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WATER POLLUTION INVESTIGATION: ERIE, PENNSYLVANIA AREA

BETZ ENVIRONMENTAL ENGINEERS, Inc.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V ENFORCEMENT DIVISION
GREAT LAKES INITIATIVE CONTRACT PROGRAM

MARCH 1975

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ERIE, PENNSYLVANIA AREA

by

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BETZ ENVIRONMENTAL ENGINEERS, INC.

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This report has been developed under auspices of the Great Lakes Initiative Contract Program. The purpose of the Program is to obtain additional data regarding the present nature and trends in water quality, aquatic life, and waste loadings in areas of the Great Lakes with the worst water pollution problems. The data thus obtained is being used to assist in the development of waste discharge permits under provision of the Federal Water Pollution Control Act Amendments of 1972 and in meeting commitments under the Great Lakes Water Quality Agreement between the U.S. and Canada for accelerated effort to abate and control water pollution in the Great Lakes.

This report has been reviewed by the U.S. Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

A study of Presque Isle Bay and its tributaries was performed to evaluate present water quality and to determine cause and effect relationships between wastewater discharges and water quality. Field sampling of Presque Isle Bay, its tributaries and Erie Harbor was performed during the fall and winter of 1973 and the spring of 1974. Special wastewater studies were performed for Penn Central and for eight select industries. Garrison Run, a tributary of Presque Isle Bay, was investigated to determine sources of wastewater entering the stream.

In general, water quality in Presque Isle Bay and Erie Harbor was good except for the presence of high levels of total and fecal coliform. Localized areas of degraded water quality were found in a few areas. Poor water quality was observed in the bay area around the confluence of Mill Creek and in the lake area adjacent to Hammermill Paper Company. Water quality in the three tributary streams was degraded and indicated the presence of sanitary and industrial wastewaters. Mill Creek appears to contribute the highest pollutional load to Presque Isle Bay.

Various continuous and intermittent wastewater discharges to Garrison Run were identified and characterized. Past operations of the Penn Central yards have produced areas where the ground is impregnated with oil. This oil is apparently discharged to Garrison Run via stormwater drains during periods of rain.

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SECTION I
CONCLUSIONS

1. Water quality in Presque Isle Bay and in Lake Erie in the vicinity of Presque Isle Bay is relatively good. Both total and fecal coliform bacteria, however, were high at various stations and exceeded state water quality criteria. Localized water quality problems exist in a few areas. Water quality is poor in the bay area around the confluence of Mill Creek and the Bay. Extremely low dissolved oxygen levels were consistently observed in this area.

Water quality is degraded in the lake area adjacent to Hammermill Paper Company. The apparent cause of this water quality degradation is the wastewater discharges from Hammermill Paper Company. Prevailing currents appear to transport highly colored water down the coastline at least as far as Fourmile Creek.

Water quality also appears to be slightly degraded in the enclosed marina area where the water intake of the Pennsylvania Electric Company (Pennelec) is located. Heated condenser discharges from Pennelec, although discharged to the open bay, recirculate back to the water intake. An annual die-off of Gizzard Shad in this area is evidently indirectly caused by Pennelec's heated discharge. This fish-kill tends to adversely affect the water quality in this area.

2. Water quality in both Cascade Creek and Mill Creek is degraded. Cascade Creek contains high levels of suspended solids, nitrogen, BOD, iron and aluminum. It also contains large numbers of total and fecal coliform bacteria. The poor water quality observed in Cascade Creek appears to be caused by wastewater discharges, stormwater runoff and a combined sewer overflow.

Mill Creek contains high levels of suspended solids, nitrogen, phosphorus, BOD, color, iron and aluminum. It also contains large numbers of total and fecal coliform bacteria. In Mill Creek, the poor water quality is apparently caused by stormwater runoff, illegal sewer discharges, industrial discharges and combined sewer overflows. Thirty-seven combined sewers discharge to the Mill Creek Tube (Dalton, Dalton and Little, 1972).

3. Water quality in Garrison Run is poor and contains high levels of color, suspended solids, BOD, iron and aluminum. It also contains large numbers of total and fecal coliform

bacteria. The degraded water quality apparently results from illegal industrial wastewater discharges, illegal sanitary discharges, stormwater runoff and combined sewer overflows. Seven combined sewers discharge to the Garrison Run Tube (Dalton, Dalton and Little, 1972). Oil contamination was also present and appeared to be caused by stormwater runoff from Penn Central.

4. Of the three tributary streams, Mill Creek appears to contribute the highest pollutional load to Presque Isle Bay. Cascade Creek appears to contribute the second highest pollutional load, and Garrison Run contributes the lowest. This conclusion is based on stream water quality and flow estimates. Stream flows were not measured.

5. Investigation of Penn Central indicated that minimal yard operations are presently being performed, but that past operations have produced areas where the ground is impregnated with oil. Stormwater apparently picks up portions of this oil and transports it, via stormwater drains, to Garrison Run.

6. Water quality at Beach 11 (Station 8) is good and may be adversely affected by the proposed filling of the area adjacent to Koppers Company with lake dredge materials.

SECTION II
RECOMMENDATIONS

1. Monitoring of the bay, lake and tributaries should be continued in order to further define the magnitude, causes and effects of the water quality problems observed. Water quality monitoring will also provide a measure of the effects of wastewater abatement measures required by state and federal agencies and recent legislation (e.g., P.L. 92-500). The monitoring program should include physical, chemical and biological measurements along with flow measurements of the three tributaries: Mill Creek, Garrison Run and Cascade Creek.

On Mill Creek, flow measurements should be made upstream just before Mill Creek enters the tube, and downstream at Station 3, located adjacent to the Erie sewage treatment plant (see Section VII).

On Garrison Run, flow measurements should be made at upstream Station 3I and at downstream Station 3A (Section VIII).

On Cascade Creek, flow measurements should be made at upstream Stations 1C and 1D, and at downstream Station 1 (See Section VII).

The monitoring program should, as a minimum, measure the following parameters: BOD, suspended solids, total coliform, fecal coliform, ammonia, nitrate, organic nitrogen, total phosphorus, ortho-phosphate, pH, temperature, color, iron and aluminum. In the bay and lake, dissolved oxygen should be measured.

Initially, the monitoring should be performed on a monthly basis to determine temporal trends. Sampling frequency should be decreased once temporal trends are established.

Spatial variations in water quality should be initially investigated by sampling many bay and lake stations once or twice for a few select parameters (e.g. dissolved oxygen, BOD, suspended solids, color, total coliform count). Regular sampling stations should be established once spatial trends are established.

2. The City of Erie, using the results of this study, should investigate Cascade Creek, Mill Creek and Garrison Run to determine the location and source of illegal sanitary or industrial connections to these streams. A program to eliminate all illegal connections should be initiated and rigidly enforced.

3. Hammermill Paper Company should take immediate steps to reduce their wastewater discharges to Lake Erie.

4. Penn Central should immediately initiate a program of oil spill prevention and clean-up as detailed in this report.

SECTION III
INTRODUCTION

Lake Erie has received much attention in the past years since it is one of the nation's largest and best known lakes and because of dramatic changes that have occurred in the lake's environment and biota (Beeton, 1965). Lake Erie is divided into three sections: the western basin, the central basin and the eastern basin. Industrial and municipal discharges have adversely affected the western basin the most. Of the three basins, the eastern basin has the best water quality and the least number of problems.

This investigation of the Erie, Pennsylvania Special Study Area was performed for the U. S. Environmental Protection Agency. The complete study included the following:

Water Quality Study of Presque Isle Bay and its tributaries.

Investigation of the Water Quality in Garrison Run and wastewaters discharging into Garrison Run.

Investigation of the Penn Central railroad yards in Erie, Pennsylvania to determine its effect on water quality in Garrison Run and Presque Isle Bay.

Investigation and evaluation of wastewater treatment facilities of eight select industries in the Erie, Pennsylvania vicinity.

The general purpose of the study was (1) to evaluate the present lake and tributary water quality in light of existing municipal and industrial discharges. (2) to obtain baseline water quality data for the evaluation of future changes in municipal and industrial discharges, (3) to provide a basis for evaluating the effects of proposed Corps of Engineers dredging on the water quality of the Presque Isle beaches, (4) to identify and evaluate wastewater discharges to the underground section of Garrison Run, (5) to determine sources of water pollution from the Penn Central railroad yard and recommend abatement measures, and (6) to review and evaluate existing wastewater treatment facilities at eight select industries and to propose wastewater abatement measures to meet Federal and State effluent and water quality criteria.

This report contains the results of the water quality study of Presque Isle Bay, its tributaries and Lake Erie. It also contains the results of the Garrison Run and Penn Central surveys. The investigation of the eight industries are contained in separate industrial reports.

This report was organized to provide (1) a review of the water quality of Eastern Lake Erie, (2) a description of the study area including the City of Erie, Presque Isle Penninsula and Presque Isle Bay, and (3) a detailed description of the water quality study and its results, including the investigation of Garrison Run and Penn Central.

SECTION IV
EASTERN LAKE ERIE

Lake Erie

Lake Erie is unique among the Great Lakes in several of its natural characteristics, each of which has a direct bearing on its condition with respect to pollution. Lake Erie is by far the shallowest of the Great Lakes and the only one with its entire water mass above sea level. It has the smallest volume, 113 cubic miles, and the shortest flow-through time, 920 days. It is the most biologically productive and the most turbid. It has the flattest bottom and is subject to the widest short-term fluctuations in water level (13 feet maximum). Its seasonal average surface levels are the most unpredictable. It is the only one of the Great Lakes with its long axis paralleling the prevailing wind direction and is subject to violent storms. Lake Erie is also the southernmost, warmest, (averaging 51°F) and the oldest (12,200 years) of the Great Lakes.

The climate of the Lake Erie basin is temperate, humid-continental with the chief characteristic of rapidly changing weather. The highest annual average monthly temperatures occur in July, ranging from 70°F to 74°F at land stations. These also generally decrease northeastwardly across the basin. The lowest average monthly temperatures occur in January at the west end of the basin and February at the east end of the basin, and range from 24°F to 28°F. The extremes of temperature in the Lake Erie basin are about -20°F and 100°F.

Average annual precipitation at land stations in the basin is well distributed throughout the year, and ranges from about 30.5 inches to more than 40 inches with an overall basin average of about 34 inches. Yearly precipitation has varied between the extremes of 24 and 43 inches. Highest precipitation occurs in the southeastern part of the basin.

Insolation (incoming solar radiation) is greatest in midsummer and least in winter. December and January ordinarily have less than 40 percent of possible sunshine, while June and July average more than 70 percent at most stations. The percentage over the lake proper in the summer is even greater.

Lake Erie and the surrounding land is important as a recreational resource. There are few wide sandy beaches on the lake, but available beaches are used at Catawba Island, Cedar Point at Sandusky, and Erie, Pennsylvania. Fishing and boating are the most popular recreational activities of Lake Erie. Swimming is also popular at many sites on the lake, although in recent years the degradation of water quality has forced periodic closings of several beaches.

A water balance of Lake Erie indicates the following significant factors: (1) annual evaporation nearly equals runoff to the lake, (2) evaporation exceeds precipitation, (3) change in storage over a long period is not significant, and (4) evaporation is greatest in late winter and in autumn.

Lake Erie is the warmest of the Great Lakes. Mid-lake surface water reaches an average maximum of about 75°F (24°C), usually in temperature the first half of August. Occasionally, the summer temperature in mid-lake surface water rises above 80°F. Near shore water normally reaches a maximum along the south shore of 80°F or more.

Eastern Lake Erie

Erie, Pennsylvania is located in the eastern basin of Lake Erie. The eastern basin is that part of Lake Erie lying east of the bar between Erie, Pennsylvania and Long Point, Ontario. It has an average depth of about 80 feet and a maximum depth of 216 feet, making it the deepest part of Lake Erie. The eastern basin has a surface area of about 2,400 square miles.

The bottom of the eastern basin consists primarily of mud which is more compact than that in the other two basins. Beaches on Lake Erie are generally narrow or absent except for Presque Isle, Pennsylvania and Long Point, Ontario which both have large natural accumulations of sand. Both of these areas have large shallow bays.

Temperature structure of the eastern basin is similar to that of the other deep Great Lakes. Thermal stratification usually occurs in the summer and sometimes in the winter. Because of seasonal overturns, mixing of the epilimnion occurs more often in the eastern basin than in the other two basins.

N. M. Burns and C. Ross (1972) studied the Lake Erie Central Basin hypolimnion. The rate of oxygen depletion of the Lake Erie hypolimnion during the summer months has been increasing since studies were initiated in 1929, although oxygen concentration at the beginning of the stratified period has not changed in 40 years. With this increase in the rate of oxygen depletion has come an early onset of deoxygenated conditions in the bottom water.

It is known that Lake Erie remains stratified for a period of about 110 days during the summer season. Therefore, a D.O. depletion rate of 3.0 milligrams/litre/month will result in an anoxic hypolimnion before the fall overturn can replenish the bottom waters. This critical depletion rate was evidenced for the first time in 1960, and even greater depletion rates have been observed in the intervening years. As a result, the Central Basin hypolimnion becomes anoxic practically every summer. Hutchinson (1957) has classified lake types according to the rate of hypolimnion oxygen depletion. A D.O. depletion of 0.025 milligrams/cc/day delimits the transition from an oligotrophic lake to a mesotrophic lake. Likewise, a D.O. depletion of 0.055 mg/cc/day indicates that a lake is eutrophic rather than mesotrophic. If we apply these limits to Lake Erie, we find that the lake becomes mesotrophic sometime around 1940, and is presently undergoing a transition from the mesotrophic to the eutrophic state.

Burns and Ross (1972) have indicated that biological processes are more important determinants of D.O. depletion rates than inorganic chemical processes. Furthermore, deoxygenation of the bottom water by organic wastes of direct human origin does not have a great significance. The main source of oxygen depleting organic material is detrital phytoplankton material that settles to the bottom where it is decomposed by bacteria. It appears, therefore, that the recent accelerating trend in the hypolimnion D.O. depletion rate in Lake Erie is due primarily to nutrient enrichment originating from the large cities on the lake.

The average sediment oxygen demand for the central basin hypolimnion was found to be 1.6 gmO_2/m_2/day in June, 1970, (Burns and Ross, 1972). Eutrophic lakes generally have sediment oxygen demands considerably below this level so the summer situation in Lake Erie must be viewed as a problem.

Glooschenko et.al (1974) studied primary productivity in lakes Ontario and Erie. Primary production varied in Lake Erie's three basins. The Eastern Basin had the highest productivity values in the spring with a midsummer decline and small peaks in the fall. Assimilation numbers were highest in the Western Basin (up to 3.5 mg C/mg chlorophyll per hour).

In the spring the highest primary productivity values were recorded along the southern shore of the lake. In the summer and autumn the areas of highest productivity were the Western and Eastern Basin regions, specifically near Erie, Pennsylvania in the Eastern Basin. The water off Erie, Pennsylvania was a region of high production in contrast to the rest of the eastern half of the lake.

SECTION V
CITY OF ERIE

The City of Erie is located in the northwest corner of Pennsylvania on the southern shore of Lake Erie. The average annual temperature is 50.5°F. Average February temperatures range from 28°F to 24°F with annual minima ranging from 0° to - 15°F. No temperature lower than -16°F or higher than 98°F has ever been recorded in Erie County. Precipitation falling as rain or snow averages 36 inches per year.

In general, it has been estimated that the Erie City area receives 60 to 70 percent of possible summer sunshine and 40 to 50 percent of possible winter sunshine. Lake Erie also exerts a moderating effect on fall temperatures. During winter the ground is frozen to a depth of 25 to 30 inches. Ice can usually be found upon Lake Erie as early as mid-December and remains until mid-April, prolonging the cooler winter season and deferring the budding of trees and shoots until a relatively later date.

The total population of Erie City was 129,231 when the last census was taken in 1970. Erie County had a population of 263,654. The population of Erie City and the surrounding area has grown since the last census, although at a rate lower than in previous years. This decline in population growth rate has been attributed to a lower birth rate combined with an emigration from Erie County. Within Erie City itself, a migration from inner city regions to the suburbs has been evidenced. Population density in Erie City has been recorded as more than eleven persons per acre. Many of the outlying rural areas in Erie and Crawford counties average less than one person per ten acres.

There are 486 industrial plants in Erie County, the majority of these are within or very close to the Erie City area. A list of major industries in Erie is presented in Table 1. The Erie City Chamber of Commerce reports that industrial plants employ 43,589 workers. They have estimated that the value of production and related activities attributed to industry is $1,403,894,000. It is evident that industry plays a very important role in the economy of Erie County and its development has, therefore, been encouraged.

Agricultural development of land in Erie County is also important economically. While agriculture is virtually non-

TABLE 1

INDUSTRIES IN ERIE, PENNSYLVANIA

Industry	Product	Employment
American Meter Company, Incorporated	Gas Meters	575
American Sterilizer Company	Hospital Equipment	1,185
Bliley Electric Company	Quartz Crystals	200
Bucyrus-Erie Company	Excavating Equipment	765
Continental Rubber Works	Mechanical Rubber Goods	450
Cooper Pennjax	Oil Field Machinery	500
Copes-Vulcan, Incorporated	Boiler Controls and Soot Blowers	463
Corry-Jamestown Corporation	Metal Office Equipment	708
Electric Materials Company	Rolled Copper Products	362
Elgin Electronics, Incorporated	Electronic Components	550
Erie County Plastics Corporation	Injection Molded Plastics	350
Erie Foundry Company	Forging Hammers and Hydraulic Presses	250
Erie Malleable Iron Company	Malleable Castings	500
Erie Marine Division, Litton Industries	Bulk Ore Carriers	300
Erie Strayer Company	Clamshell and Concrete Buckets	255
Erie Technological Products, Incorporated	Electronic Components	700
Eriez Magnetics	Magnetic Equipment	300
Fenestra Division	Steel Doors, Metal Building Partitions	223
Firch Baking Company	Baked Goods	250
GAF Corporation	Roofing, Siding, Insulation	225
General Electric Company	Locomotives, D.C. Motors and Generators	11,387
Hammermill Paper Company	Fine Writing and Printing Papers	2,026
Hoover Ball and Bearing Company, Quinn-Berry Division	Injection Molded Plastics	200
Kaiser Aluminum and Chemical Corporation	Aluminum Forgings	550
R. M. Kerner Company	Custom Machine Shop	250
Lord Manufacturing Company	Bonded Rubber Products	1,500
Marx Toys	Toys	1,000
McInness Steel Company	Forgings	255
Molded Fiber Glass Boat Company	Fiberglass Boats	300
National Forge Company	Heavy Steel Castings, Forgings and Ingots	900
Parker White Metal Company	Injection Molded White Metal Products	490

TABLE 1 (cont'd)

INDUSTRIES IN ERIE, PENNSYLVANIA

Industry	Product	Employment
Penn Brass and Copper Company	Copper and Aluminum Tubing	250
Perry Plastics, Incorporated	Injection Molded Plastics	225
Raymond division, Associated Spring Corporation	Mechanical Springs	590
Riley Stoker Corporation	Boilers	600
Skinner Engine Company	Steam Engines	142
A. O. Smith Corporation	Service Station Equipment	702
Sterling Seal Company	Caps and Closures	550
Teledyne Penn-Union Electric	Connectors for Electrical Industry	500
Uniflow Manufacturing Company	Water Pumps, Coolers	250
Urick Foundry Company	Iron Casting	225
Weil-McLain Company	Radiators and Boilers	148
White Consolidated Industries, Inc. Speciality Valve & Control Div.	Valves and Controls	215
Zurn Industries, Incorporated	Mechanical Power Transmission Products, Castings	2,000+

Source: City of Erie Chamber of Commerce existent within the City of Erie, farms occupy a large percentage of total county land. Recent surveys have disclosed that the number of persons employed in the agricultural sector of the Erie County economy have declined since 1950. It is estimated that in 1950, 4.3 percent of the work force was employed in farm-related activities. Currently, less than 2 percent of the work force is employed by agriculture. While these figures show a marked deflation of the agricultural economy, they have been partially offset by an increase in the average acreage per farm. The most important agricultural activity in the county is dairy farming. One-third of the agricultural economy involves dairy products. Following dairy farming, income from fruits, field crops, and vegetables rank in importance.

Land use for recreational activities totals only 1 percent of Erie County land, yet a diversity of recreational opportunities exist. Presque Isle State Park, located in the City of Erie, is a very important recreational resource. Within Erie City, Glenwood Park and its public zoo serve the population. There is a yacht club in Erie and a large marina on Presque Isle offering ramps, boat liveries, and lifts. Lake Erie and inland lakes provide sport fishing for lake-run rainbow trout, smelt, muskellunge, small mouth bass, largemouth bass, walleyes, coho salmon, northern pike, crappies, perch, panfish and rock bass. City outdoor recreational facilities include 27 playgrounds, 4 neighborhood play lots, 2 community recreation parks, 1 swimming pool operated by the City, 14 wading pools, 12 softball fields, 28 tennis courts, 4 ice skating rinks, and 2 stadiums. There are 15 private and public golf courses near or within the Erie City limits. Other activities available to Erie residents are skiing, snowmobiling, swimming, theatres and thoroughbred racing.

Erie County is an area of diversified industry. Many of these industries have water requirements and discharge industrial wastes. Most of the industries with water requirements are manufacturing industries. In Erie City the primary users of the public water supply include Continental Rubber Works, The Erie Brewing Company, the GAF Corporation, Kaiser Aluminum, Lord Manufacturing, National Forge, and the Urich Foundry. Other small industries use less water, but these are the major users of municipal water. Self-supplied water is used by 10 industries in Erie County. Hammermill Paper Company and Interlake Iron are two private concerns removing over four billion gallons of water per year from outer Erie Harbor. Libby Products and Ohio Rubber use

56 million and 91 million gallons of water per year, respectively, and the remaining 6 self-supplied industries use ten million gallons per year. All of these industries except Gunnison Brothers Tannery, lie within the service areas of water companies. The Pennsylvania Electric station is the only publicly-owned power plant using lake water for cooling purposes. The plant requires 51 million gallons of water per year.

May of the industries listed previously discharge industrial wastes into Presque Isle Bay and into tributaries feeding the bay. However, the major amount of industrial waste discharge originates from the Hammermill Paper Company. A wastewater flow of 20 mgd discharges directly into Lake Erie from Hammermill. This wastewater contains about 62,000 pounds/day of BOD; 530,000 pounds/day of total solids; 8,400 pounds/day of suspended solids and 51,000 pounds/day of sulfate. The Hammermill Paper Company's wastewaters account for seven percent of the total industrial waste discharge to Lake Erie. Twenty-four industries discharge into surface waterways in the vicinity of Erie City. The other industrial waste discharges in the study area are served by municipal sewage treatment plants. These industries must pretreat their toxic wastes before they are permitted to enter the municipal sewage system.

Heated water is discharged by many industries. Presently there is little data on heated discharges by these industries. The following industries discharge heated waters (U.S. Army Corps of Engineers, 1973).

1. Koppers Corporation - Withdraws 85 percent of its process waters and returns over 4 million gallons of treated wastewater to the Erie outer harbor daily. The average temperature difference between the effluent and lake water is 35^{o}F in winter and 25^{o}F in summer.

2. Pennsylvania Electric Company - Obtains over 99 percent of its process water from Presque Isle Bay. The temperature differential between the effluent and lake water is 35^{o}F in winter and 25^{o}F in summer.

3. National - Erie Forge - utilizing the metropolitan water works for its water supply has an average influent - effluent temperature difference of 11^{o}F during the summer.

4. The Gunnison Brothers Tannery - has an influent - effluent temperature difference of 10^{o}F in winter and 0^{o}F in summer.

5. General Electric Company - has an influent - effluent temperature differential of 10^{o}F during both the winter and the summer.

6. Hammermill Paper Company - has an influent - effluent temperature differential of 45^{o}F during the winter and 10^{o}F during the summer.

Many industries in the Erie City area use water from municipal and private supplies for their industrial processes. Industrial waste is discharged to both Lake Erie and to the municipal sewers. In terms of flow, the largest discharges to surface waterways are:

1. Hammermill Paper Company - Discharges 20 mgd of effluent into Lake Erie.

2. Koppers Corporation - Discharges 4 mgd of effluent into Lake Erie.

3. Pennsylvania Electric Company - Discharges 149 mgd of cooling water into Presque Isle Bay.

4. General Electric Company - Discharges over 4 mgd of effluent into an unnamed tributary paralleling 4-Mile Creek.

Sewage Treatment Facilities

The City of Erie presently has a wastewater treatment plant providing secondary treatment to the wastewaters from Erie and from four townships and one borough. Existing activated sludge treatment facilities were expanded in 1974 from a capacity of 45 mgd to a design capacity of 65 mgd. Total estimated population served is 173,730 (Engineering - Science, 1974). Effluent characteristics of the treatment plant prior to its expansion are presented in Table 2. Removal rates for BOD and suspended solids for the unexpanded plant were 65 and 67 percent respectively.

Effluent characteristics of the expanded treatment facilities have improved significantly. BOD and suspended solids removal rates average about 87 and 79 precent respectively for the expanded facilities. The expanded treatment plant uses vacuum filtration, incineration and landfill for the treatment and disposal of sludge.

TABLE 2

PERFORMANCE OF ERIE
WASTEWATER TREATMENT PLANT[1]

MAY 3, 1973[3]

Analyses[2]	Influent	Effluent	Percent Removal
Temperature °C	17	-	-
pH	7.5	7.7	-
Dissolved Oxygen	-	5.0	-
Color (Units)	25	35	-40
Turbidity (Units)	80	10	88
Alkalinity (mg/l)	170	190	-12
Total Iron (ug/l)	2720	1060	61
Sulfate (mg/l)	31	30	3
Manganese (Mn) (ug/l)	260	240	8
COD (mg/l)	224	94	58
Total Phosphorus	3.06	2.46	20
Total Soluble PO_4	1.60	1.81	-13
5 Day BOD (mg/l)	98	34	65
Nitrate (mg/l)	2.31	2.48	-7
Ammonia (mg/l)	8.5	11	-29
Chloride (Cl) (mg/l)	86	58	33
Oils (mg/l)	5.8	3.2	45
Phenols (ug/l)	12	4	67
Copper (ug/l)	150	110	27
Zinc (ug/l)	470	250	47
Chrome (ug/l)	140	90	36
Aluminum (ug/l)	1830	500	73
Lead (ug/l)	56	20	64
Mercury (ug/l)	2	2	0
Total Solids (mg/l)	688	516	25
Suspended Solids (mg/l)	240	80	67

Notes: (1) Source: Engineering-Science, 1974
(2) Analysis made on 24-hour, flow-weighted, composite samples
(3) Plant was expanded in 1974.

The sewer system of Erie City consists of sanitary sewers, storm sewers, and combined sewers. Recently built sewers are not of the combined variety, but the older lines dating back to just after the Civil War are combined. Overflow arrangements to the combined system have been added in order to obtain manageable flow rates in the sewer system, preventing local flooding, and flooding at the sewage plant. There are 59 known combined sewer overflows, most of which have been added since the original sewer installation. There are five outlying pumping stations in the sanitary-combined sewer system. Distribution of the total annual combined sewer overflow is presented in Table 3.

Presque Isle Peninsula

The Presque Isle Peninsula is located in Erie, Pennsylvania, on the south shore of Lake Erie. The peninsula's long axis is oriented in an east-west direction. It arises from the south shore of the lake near the City of Erie where it is connected to the mainland by a narrow neck of sandy terrain several hundred feet in width. There are four major and several minor sand ridges extending along the peninsula. Stretching from the eastern end to the western end of Presque Isle; these ridges form an intricate network of ponds and dunes.

Geologically, Presque Isle is less than 1,300 years old. It was formed as beach and sand dune deposits were carried into the vicinity by predominant lake currents. Since the initial formation of Presque Isle, the land mass has changed shape considerably, migrating in an easterly direction. A migration of 1/2 mile east has taken place in the past 100 years. The peninsula has moved 5 miles to the east since its origin. The predominant littoral current continuously carries beach material to the eastern tip of the peninsula, where conflicting current patterns push the sedimentary material landward to give the spit a hook-like shape. Northeasterly storm winds are responsible for the creation of sand dune ridge patterns. Finally, the conflicting effects of wind and vegetal cover are instrumental in building dune and soil topography. Soils of the peninsula are sandy and have a low resistance to erosion. Fine sand is carried shoreward by winds and along shore by waves and currents. Only coarse sand stops near the water's edge. The bedrock of the peninsula is shale and sandstone of the Devonian period.

Practically the entire peninsula is owned by the State of Pennsylvania and has been preserved as a park. The population of Presque Isle is therefore dependent upon the number of

TABLE 3

DISTRIBUTION OF TOTAL ANNUAL COMBINED SEWER OVERFLOW CHARACTERISTICS

Location	Flow MG Per Year	BOD_5 Pounds Per Year	Suspended Pounds Per Year	Solids Pounds Per Year
Mill Creek	220	71,000	645,700	4,020
Garrison Run	26	37,000	37,000	2,160
West Side	45	15,700	98,800	730
East Side	9	4,300	25,500	90
Total	300	128,000	807,000	7,000

Source: Dalton-Dalton-Little (1971)

tourists visiting the park. There is no significant "permanent" population. In 1971, more than 3.5 million persons visited the park. Over half of these came to Presque Isle in the summer months (U.S. Army Corps of Engineers, 1973).

Recreational uses of Presque Isle cover a broad range of activities. Recreational use is perhaps the most important function of Presque Isle. The park has facilities for bathing, boating, hiking, fishing, and picnicking. Other activities offered to the park's visitors include sight-seeing, driving, bicycling, bird watching, and photography. Plans have been formulated for a restaurant and museum in the vicinity of Misery Bay. Fishing is good in the State Park. Sport fish taken on the peninsula include largemouth bass, bluegills, sunfish, crappies, bullheads and catfish. Bowfisherman take carp, spotted and longnosed gar, and bowfins. Perhaps the most attractive aspect of the park is the beach area. There are eleven sandy beaches of excellent quality on Presque Isle. Facilities at these beaches include parking lots, developed bathhouses, and refreshment facilities. In 1965 the Corps of Engineers constructed a large marina on Presque Isle. This marina is capable of handling 2,000 boats up to 45 feet in length. The entrance to the marina has been built to allow easy access to Presque Isle Bay and Lake Erie.

There are no industries located on Presque Isle. Therefore, there is no need for industrial waste disposal systems. Because of the large number of people frequenting the park during the year, sanitary facilities are very important. Water and electric lines have been extended out to the tip of Presque Isle. These lines effectively serve the entire peninsula. There are, however, no sewers on Presque Isle. Neither can septic tanks be constructed there because of the high water table. The park has remedied this problem by placing aerated, chlorinated, chemical pit toilets at appropriate localities around the peninsula. The City of Erie obtains water from the outer shore of Presque Isle through two water pipes crossing the peninsula at different localities.

SECTION VI
PRESQUE ISLE BAY

General

Presque Isle Bay is in the eastern basin of Lake Erie. It is enclosed by the mainland and the City of Erie to the south, and by the Presque Isle Peninsula to the north. There are two watersheds that supply water to the bay. These are the Cascade Creek and Mill Creek watersheds. The Erie Metropolitan water commission has determined that Cascade Creek has a drainage area of 13.06 square miles. The only metropolitan area on the perimeter of Presque Isle Bay is the City of Erie. However, there are many recreational and commercial facilities located on the bay.

The length of Presque Isle Bay has been measured to be 4.75 miles. This length represents the maximum fetch of the bay itself. The width of the bay, measured along a transect perpendicular to the maximum length, is 1.75 miles. The maximum length of the bay lies on an axis running from the southwest to the northwest. Total surface area of Presque Isle Bay has been determined to be 3,178 acres. This surface area includes a 35-acre marina constructed by the U.S. Army Corps of Engineers on Presque Isle. The maximum depth of Presque Isle Bay is 28 feet in the navigation channel, an area which has been and continues to be dredged regularly by the Corps of Engineers. Maximum depth occurs just north of the port of Erie. Bathymetric surveys have been conducted on Presque Isle Bay, but depths in this relatively small body of water are subject to fluctuations due to rainfall and seiches. The total volume of Presque Isle Bay is estimated to be 13,800 million gallons (U.S. Army Corps of Engineers, 1973).

Recreationally, Presque Isle Bay is a very important resource. The Bay is an excellent harbor for small craft, and the marina on Presque Isle affords a protected and convenient anchorage for boatsmen on the Great Lakes-St. Lawrence Waterway system. Although the quality of water within Presque Isle Bay itself has become degraded in recent years, the County Department of Health has indicated that it does not consider the bay to be grossly polluted. Fishing is quite good in some areas of the bay, particularly in the vicinity of Misery Bay. Recreational uses of Presque Isle Bay are illustrated in Figure 1.

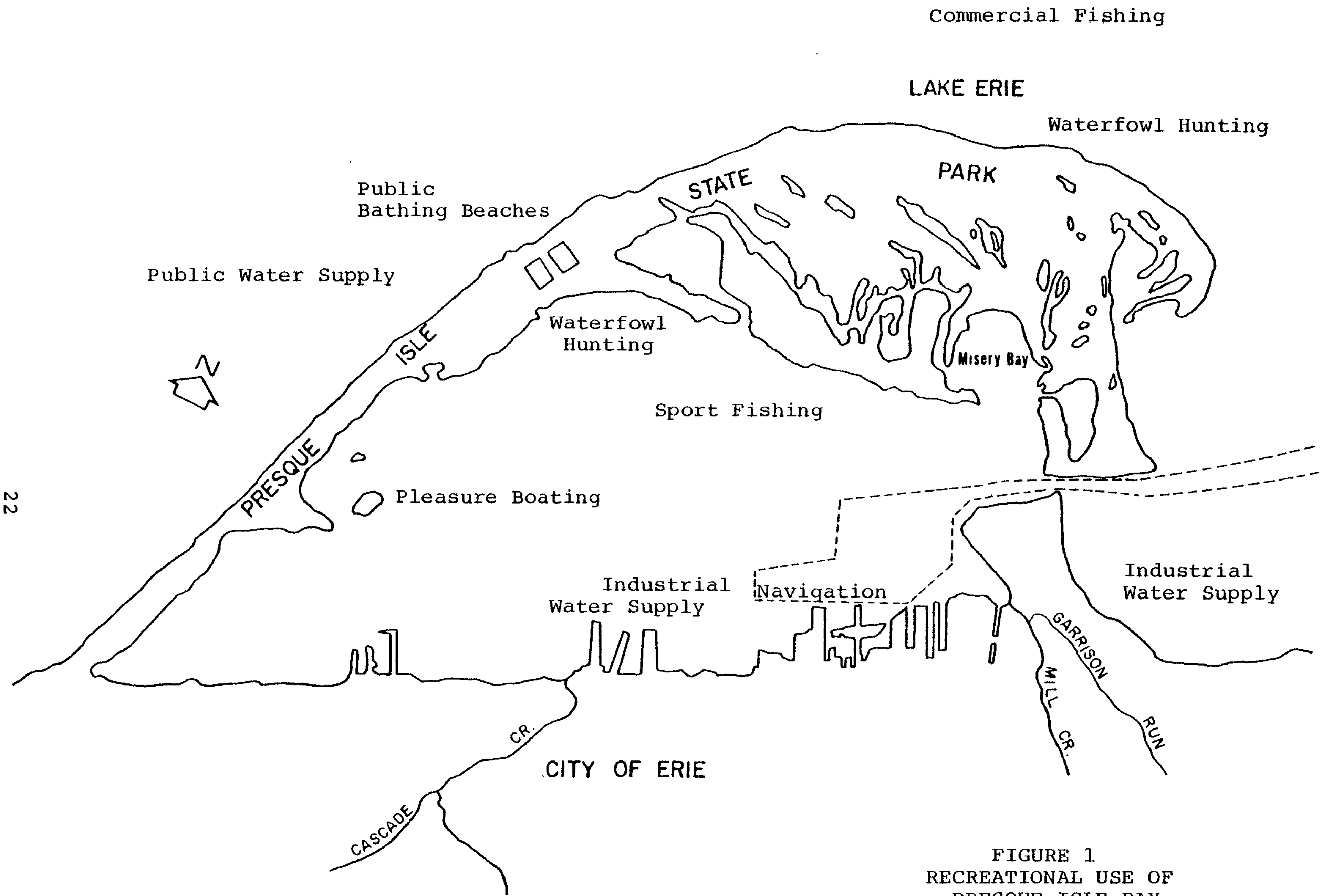


FIGURE 1
RECREATIONAL USE OF
PRESQUE ISLE BAY

Industrially, the bay is used quite extensively. Erie County is primarily a metals and metal products manufacturing area. The Erie area produces materials in over 100 different classifications. The port of Erie exports oil, heavy machinery, pig iron and lumber. Received cargo consists of limestone, sand, petroleum, and newsprint. The harbor in Presque Isle Bay is considered to be one of the best in the Great Lakes. It is both a lake and a world port. However, maintenance dredging is necessary to keep the port in operation. Industrial uses of the bay are illustrated in Figure 2.

There are a variety of habitats within Presque Isle Bay with distinct differences between the Presque Isle Peninsula and the mainland shore.

In a recent study conducted by Aquatic Ecology Associates (1973) for the Pennsylvania Electric Company, the inner and outer shorelines of the bay were separated into several distinct zones, each with a unique habitat and species composition. (See Figure 3). Zone One, the shoreline along the waterfront of Erie, is an area of heavy industrial concentration. The natural habitat there has been changed significantly by industrial activity. Physical and chemical alterations have included dredging activities, construction of harbor facilities, and the discharge of municipal and industrial wastes. Zone One has been characterized as "one of fluctuating water quality with a bottom composed of thick organic muds generally lacking in an abundance of submerged aquatic vegetation".

Zone Two covers a large portion of the mainland shore near the City of Erie. Consistently, there is a shoreline of rock and rubble in this area. Much erosion has taken place on this shoreline in previous years, but the largest detriment to water quality in Zone Two appears to be Cascade Creek (Aquatic Ecology Associates, 1973). A considerable amount of municipal and industrial waste enters the bay through Cascade Creek. The water quality in this area appears to fluctuate and there is, again, an organic mud bottom. In Zone Two, however, a dense growth of aquatic vegetation was found on the bay bottom.

Zone Three covers the bulk of the Presque Isle shoreline. Because the state park occupies the entire mainland area behind this shoreline, there is no industrial or municipal waste discharge into the bay from Zone Three. Immediately offshore from Zone Three, Presque Isle Bay is very shallow. The bathymetric map of the bay shows depths of 1, 2, 3 and 5 feet in this area. Only at the extreme southern end of the zone is there a drop to 13 feet. The underwater topography of the bay forms a very gently sloping gradient in most of Zone Three. The substrate found on the bottom of the bay in this

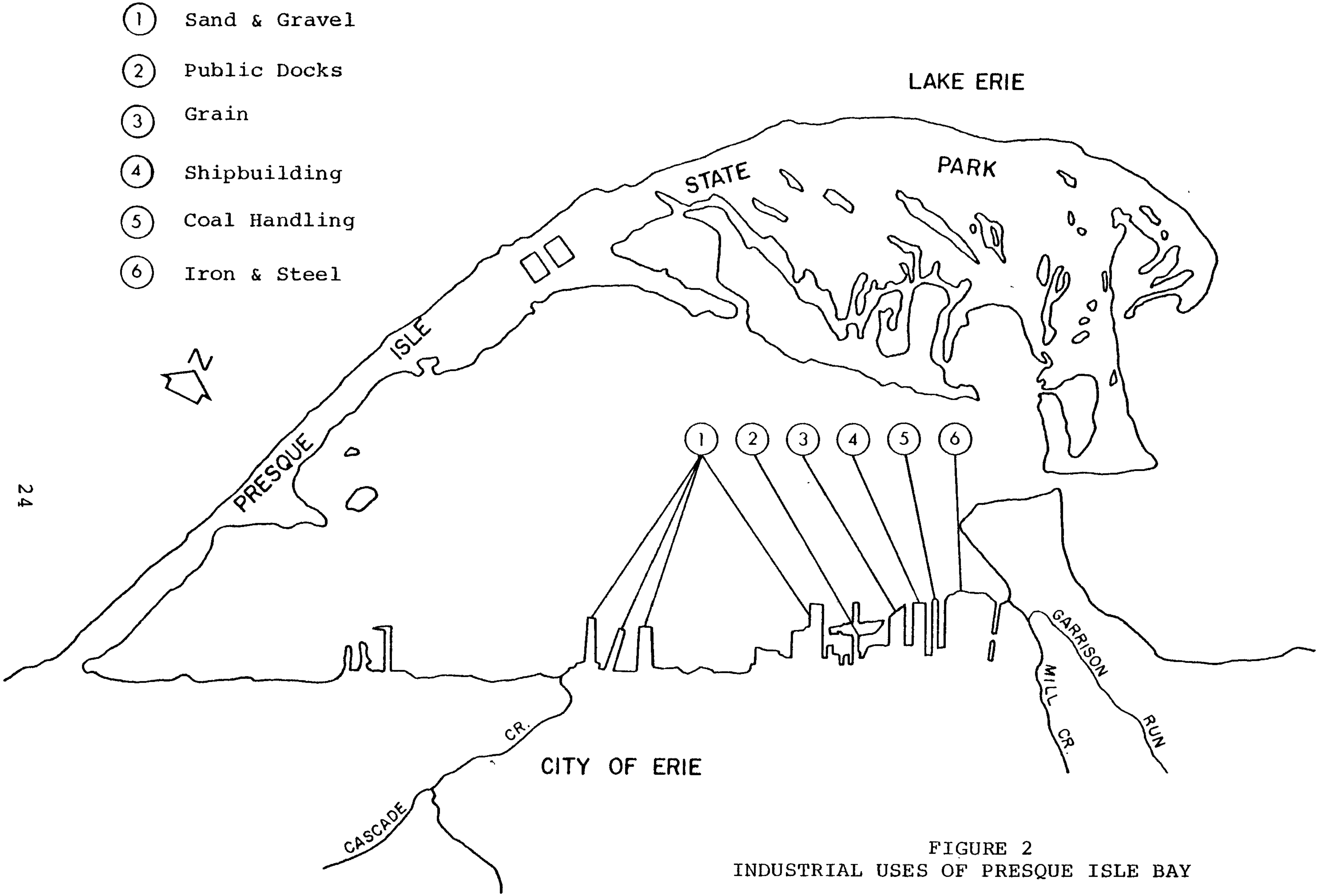


FIGURE 2
INDUSTRIAL USES OF PRESQUE ISLE BAY

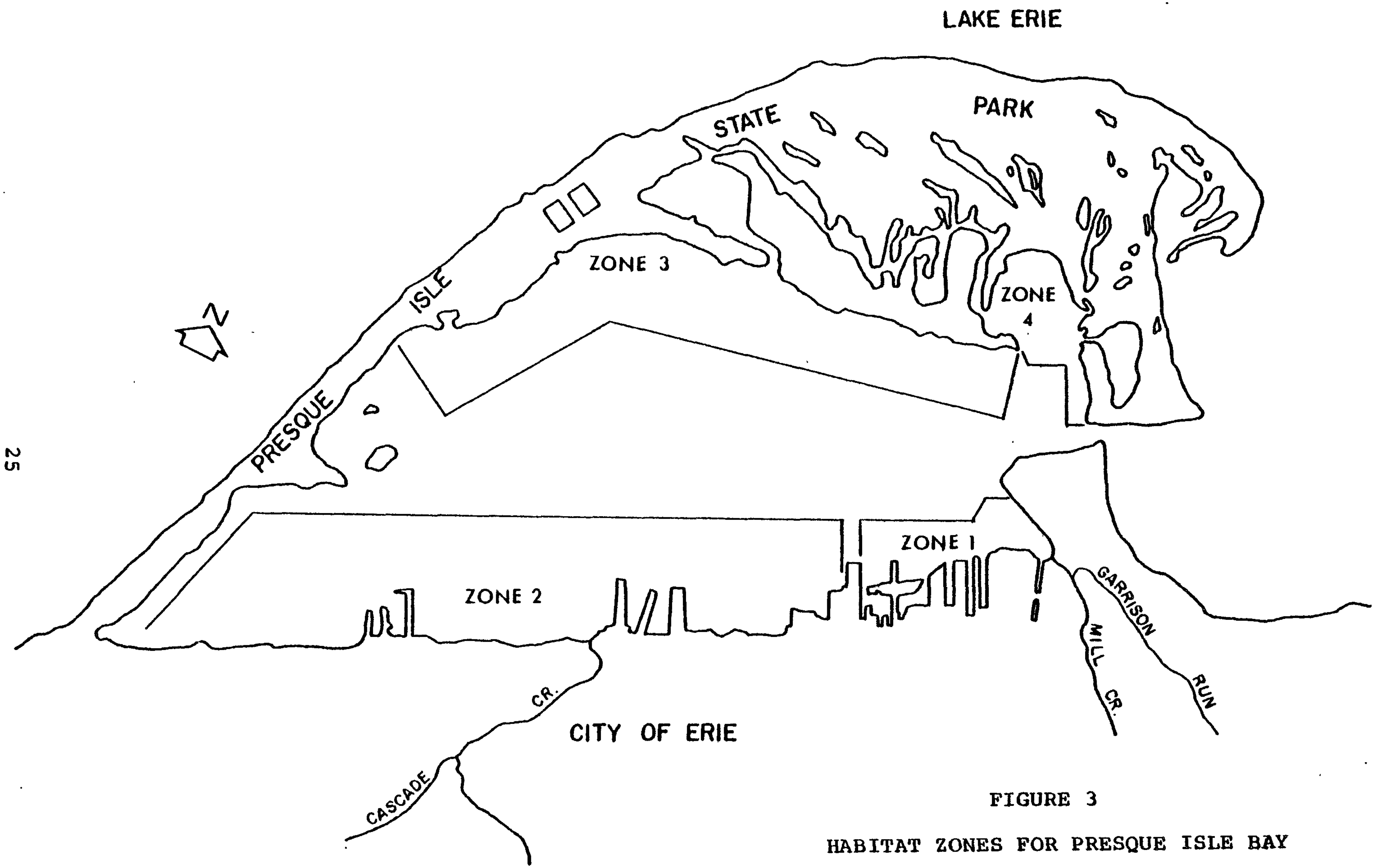


FIGURE 3

HABITAT ZONES FOR PRESQUE ISLE BAY

Source: Aquatic Ecology Associates (1973) study area could be described as sandy and free of organic mud and debris. There is very sparse growth of aquatic vegetation in Zone Three. Zone Four covers the remainder of the Presque Isle shoreline in the Misery Bay area. The habitat there has been characterized as a unique, well sheltered area occupying the enlarged terminus of an extensive lagoon system. A combination of mud and sand covers the bottom of the bay in this area. Very thick growths of rooted aquatics have been noted. It is, perhaps, the organic material contributed by these plants that is responsible for much of the mud on the bay bottom of Zone Four. There is no evidence of any municipal or industrial waste entering the bay in Zone Four.

Each of these zones is capable of supporting a different habitat-specific community. Studies on the fish living in each zone were performed in 1973 for the Pennsylvania Electric Company. Forty-three total species were identified and ten were common to all four zones. Zone One, with the least habitat diversity, supported sixteen species, Zone Two supported eighteen, Zone Three supported twenty-four and Zone Four supported thirty-one. (see Table 4).

The water quality of Presque Isle Bay has been studied on several different occasions. Results of studies performed by the Great Lakes Research Institute (1972, 1973) for the Erie County Department of Health indicate a general trend of improvement in water quality of Lake Erie in the vicinity of the Presque Isle beaches. Water temperature exhibited the same annual pattern in several studies. The water temperature increased steadily to a maximum peak value in July, after which it decreased in a seasonal pattern. The pH of the water was slightly basic at all times. Inside Presque Isle Bay the pH was slightly lower than it was on the lake side of Presque Isle. A 1972 study of the bay recorded a mean phytoplankton population of 1.3×10^5/liter. Chlorophyta comprised nearly 50 percent of the algae. Cyanophyta comprised 6 percent to 25 percent of the total number.

Coliform studies on the bay indicated that water quality there was not good. Water contact sports could not be permitted at any time in the bay. All other recreational and aquatic uses could be permitted with few exceptions. Microbiological studies were conducted at Presque Isle in 1963 to 1964 (U.S. Dept. of Interior, 1968). Low coliform counts were measured on the west side of the peninsula near the shore. Results from sampling stations located north and northeast of the Isle indicate a substantial increase in coliform counts. A corresponding increase in coliforms was measured in Erie Harbor. Median total coliform values of

TABLE 4

COMPOSITION OF FISHES IN
PRESQUE ISLE BAY

Economic Classification	Precent Composition by Zones					
	1W*	1S*	2	3	4	Total
Sports	24	27	15	26	26	23
Commercial	16	17	27	8	14	15
Fine Food	27	27	27	24	23	21
Coarse Food	8	7	11	8	14	12
Forage	19	15	9	26	12	21
Other	6	7	11	8	11	8

*W = Winter *S = Summer

2,100 to 17,000 organisms per 100 ml were measured in Erie Harbor stations located near Mill Creek and in the ship channel. A maximum total coliform count of 520,000/100 ml was recorded in this area. Median fecal coliform densities in waters north and east of Presque Isle ranged from 3 to 13 percent of the total coliform counts, and fecal streptococci counts averaged from 1 to 10 organisms per 100 ml. Mill Creek is probably the source of this pollution. *Salmonella* organisms were isolated from 80 percent of the samples collected in both Mill Creek and the harbor. *Salmonella* was found in the City of Erie's sewage. In general, water quality west of Presque Isle was found to be satisfactory for swimming purposes. Water quality north and east of Presque Isle varies considerably with maximum total coliform counts of 2,800 to 15,000 organisms per 100 ml. This indicated that pollution entered the lake intermittently, causing a health hazard in the area along the eastern shore. Recent studies have verified these high total and fecal coliform counts (GLRI, 1972, 1973).

Heavy metal analyses were performed during the 1972 study mentioned previously. Copper concentrations occasionally were found to be in excess of the acceptable limit concentration. Aluminum concentrations were consistently high in the bay, and usually exceeded the acceptable level of concentration. Nickel and zinc were rarely above their detection limits of 10 and 20 ug/l. No chlorinated pesticides were detected in the 1972 study, and only rarely were traces of other chlorinated organics detected. To generalize, the water quality in Presque Isle Bay is not good, neither is the water grossly polluted. In 1972, coliform, copper and aluminum pollution were the most serious problems. The natural habitats of the bay have been physically and chemically altered by industrial and municipal interference. It is therefore inevitable that the community ecology of the area has been changed to a certain extent.

Sediment in Erie Harbor

In 1973, a sampling program of the sediment inside Presque Isle Bay was conducted for the Pennsylvania Department of Environmental Resources Bureau of Water Quality Management. Industrial and wastewater constituents enter the sediments and accumulate in Presque Isle Bay. The sediment study was conducted to clarify long-term aspects of bay ecosystem quality. Localities of the sampling station are shown in Figure 4. Analyses were performed for: dry solids, BOD, sulfides, chemical oxygen demand, oil and grease, total Kjeldahl nitrogen (TKN), and total phosphate. The results of this study are presented in Table 5.

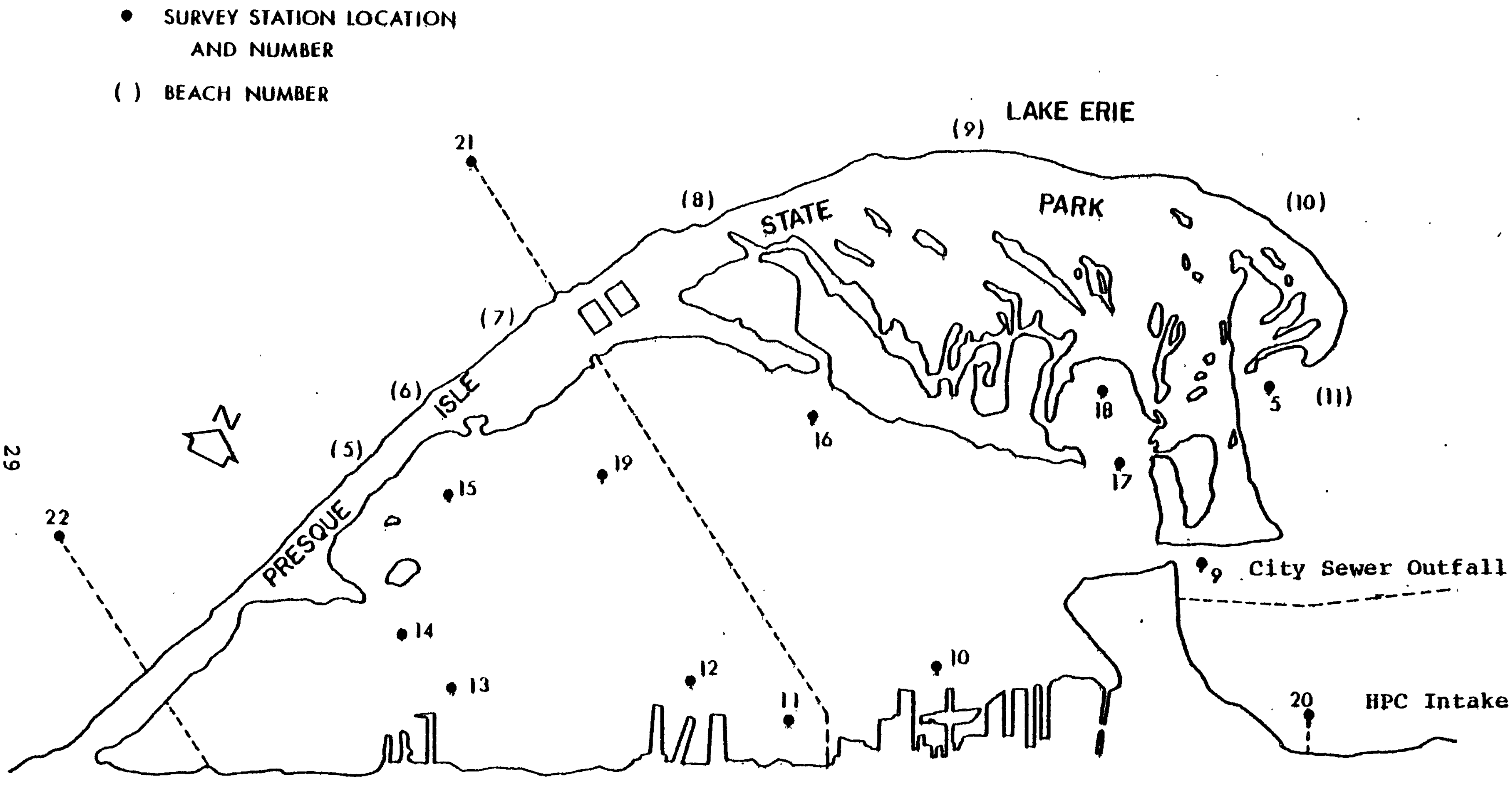


FIGURE 4

PRESQUE ISLE BAY SEDIMENT STATIONS

Source: Engineering - Science, Inc. (1974)

TABLE 5

PRESQUE ISLE BAY SEDIMENT SURVEY: PHYSICAL AND CHEMICAL MEASUREMENTS

	PHYSICAL			CHEMICAL						
Station	Depth (ft)	Volume (l)	Color	Dry Solids (%)	BOD_5 (mg/g)	Sulfides (mg/g)	COD (mg/g)	Oil & Grease (mg/g)	TKN (mg/g)	Total PO_4-P (mg/g)
5	4.5	0.4	Brown	23.7	0.46	0	1.49	0.20	0.056	0.056
9	13.5	0.25	Black	75.5	0.48	0	3.35	0.14	0.161	0.053
10	25.0	3.0	Black	37.4	9.58	0.022	100.70	1.61	1.888	0.045
11	11.0	1.5	Black	38.5	12.80	0.186	129.57	3.75	2.616	0.075
12	21.0	2.0	Black	41.0	11.40	0.097	147.75	3.57	2.687	0.027
13	17.5	1.5	Black	27.8	12.72	0.038	138.89	1.33	3.708	0.0
14	11.0	2.0	Brown/Black	70.4	1.37	0.004	12.42	0.42	0.448	0.078
15	13.5	0.6	Grey/Black	62.7	2.26	0.026	16.13	0.08	0.829	0.068
16	15.5	0.8	Grey/Black	69.1	1.36	0.038	8.77	0.18	0.294	0.062
17	13.0	1.5	Grey/Black	21.2	13.49	0.058	187.18	2.19	5.712	0.050
18	12.0	2.0	Black	19.8	12.71	0.066	221.72	2.32	6.260	0.117
19	19.0	1.8	Black	23.2	22.01	0.080	165.49	2.09	4.592	0.181

Source: Engineering-Science, 1974.

The 1973 sediment study showed that sediments along the north shore of Presque Isle Bay were high in sand content (63 to 70 percent dry solids), and low in BOD (1.4 to 2.3 mg/g), COD (9.0 to 12.5 mg/g), and TKN (0.29 to 0.83 mg/g). The lowest concentration of dry solids was located in Misery Bay (20 percent). Those individuals conducting the sediment study felt that the low concentration of dry solids indicated high organic content. High BOD (13.0 mg/g), COD (204 mg/g), PO_4-P (0.09 mg/g), and TKN (6.0 mg/g) values supported this hypothesis. It is believed that there are three important factors contributing to the build-up of organic material in Presque Isle Bay: (1) the annual die-off of natural vegetation along the shoreline, (2) the transport of materials from the outer Harbor to the Inner Harbor, (3) poor flushing in Presque Isle Bay. The oil and grease concentrations were high in Misery Bay (2.25 mg/g) even though there are no urban and industrial activities involving oil in this vicinity. This seems to indicate that the above conclusions are valid.

Along the south side of Presque Isle Bay, there are a large number of industrial and commercial activities. The sediments are, therefore, high in organic content. BOD, COD, and TKN concentrations were 10-13 mg/g, 100-148 mg/g, and 1.9-3.7 mg/g respectively. It was found, as well, that oil and grease content along this shore was high (1.3-3.8 mg/g).

It was found that many sediments roll into the "crater-like" pocket in mid Presque Isle Bay (a depth of 30 feet). Because of this, there are sediments in the mid bay region that are high in organic content. They have the highest BOD (22 mg/g) and COD (165 mg/g). The pattern of waste accumulation in the harbor was determined in the 1973 study. Outer Presque Isle Bay is receiving waste from Erie City and Hammermill Paper Company. This waste is pulled into Presque Isle Bay by a poorly defined gyre that is caused by predominant wind currents. Once inside the harbor, water is mixed with sewage overflows from the City of Erie and industrial wastewater discharge. This creates a highly organic and chemical constituent concentration inside the harbor.

In an additional sediment analysis conducted during the same 1973 study, benthic animal diversity values and sediment core samples were observed.

Cores were removed from a maximum depth of 18 inches and oil and grease determinations were made. Most of the cores collected from Presque Isle Bay had high oil and grease values. The range of oil and grease concentration encountered was 0 at a depth of 15-18 inches to 4.0 mg/g at 6 to 9 inches below the bottom of the Bay. This result seemed to indicate that oil and grease is not distributed uniformly throughout the length of the core.

A high negative correlation was found between the benthic annual diversity index and the amount of oil and grease present at a location. This is perhaps indicative of the constraint placed upon the development of desirable benthic invertebrate communities by high concentrations of oil and grease. The diversity index for invertebrates was calculated at all sediment sample stations. At all stations the benthic animal diversity number was less than one. This value would indicate a poor water quality. No benthic animals were present in the middle of the harbor. At this point, the oil and grease content was 2.09 mg/g. Along the south shore of Presque Isle Bay, low animal diversities were associated with oil and grease concentrations of 1.61, 3.75, and 3.57 mg/g. There were also low animal diversity indexes recorded along the north shore of Presque Isle Bay where oil and grease concentrations were low. Researchers attributed this low diversity to problems with the collecting dredge which failed to bite into the sandy sediments at a sufficient depth. The diversity index for the entire benthic community in Presque Isle Bay was calculated both in the summer and in the fall. In the eastern part of the bay, the ship channel and public boat basin, the animal diversity index ranged from 1.4 to 3.1 during the summer and from 0.7 to 3.0 during the fall. It was assumed that the higher benthic animal diversity index values found in this part of the harbor may be attributed to:

1. seasonal variation in community size
2. active flushing of this area by Pennelec discharge
3. annual dredging of the shipping channel

SECTION VII
WATER QUALITY STUDY OF PRESQUE ISLE BAY

Introduction

A water quality study of Erie Harbor was performed to determine existing water quality and major sources of pollution in Erie Harbor. Lasting from September, 1973 to June, 1974, the study included the monitoring of physical, chemical and biological characteristics of Presque Isle Bay, its tributaries and Lake Erie in the vicinity of Erie, Pennsylvania. In general, water samples were collected at ten stations for each of six water quality surveys. Four of the surveys were conducted in the fall and winter of 1973 while two were conducted in the spring of 1974. Summer conditions could not be studied because of project time constraints. Additional samples were collected from specific lake and stream locations during the study to provide in-depth information on sources of water quality degradation.

Water quality surveys of Erie Harbor were performed in September, October and December of 1973 and in May and June of 1974. Ten sampling stations were sampled during each survey with the exception of the December 27, 1973 survey when a few stations could not be sampled due to unsafe ice conditions. The location of the ten basic sampling stations are shown in Figure 5 and are described below:

- Station 1 - Cascade Creek just above confluence with Presque Isle Bay.
- Station 2 - Presque Isle Bay about 200 feet from the south shore directly opposite the confluence of Cascade Creek and Presque Isle Bay.
- Station 3 - Mill Creek just downstream of the Erie sewage treatment plant and upstream of its confluence with Presque Isle Bay.
- Station 4 - Presque Isle Bay about 200 feet out from the confluence of Mill Creek and the bay.
- Station 5 - Mid-point of Misery Bay.
- Station 6 - Lake Erie about 500 feet north of Hammermill Paper Company.
- Station 7 - Lake Erie directly east of channel leading from Presque Isle Bay to Lake Erie.
- Station 8 - Lake Erie about 300 feet east of Beach 11 on Presque Isle Peninsula.

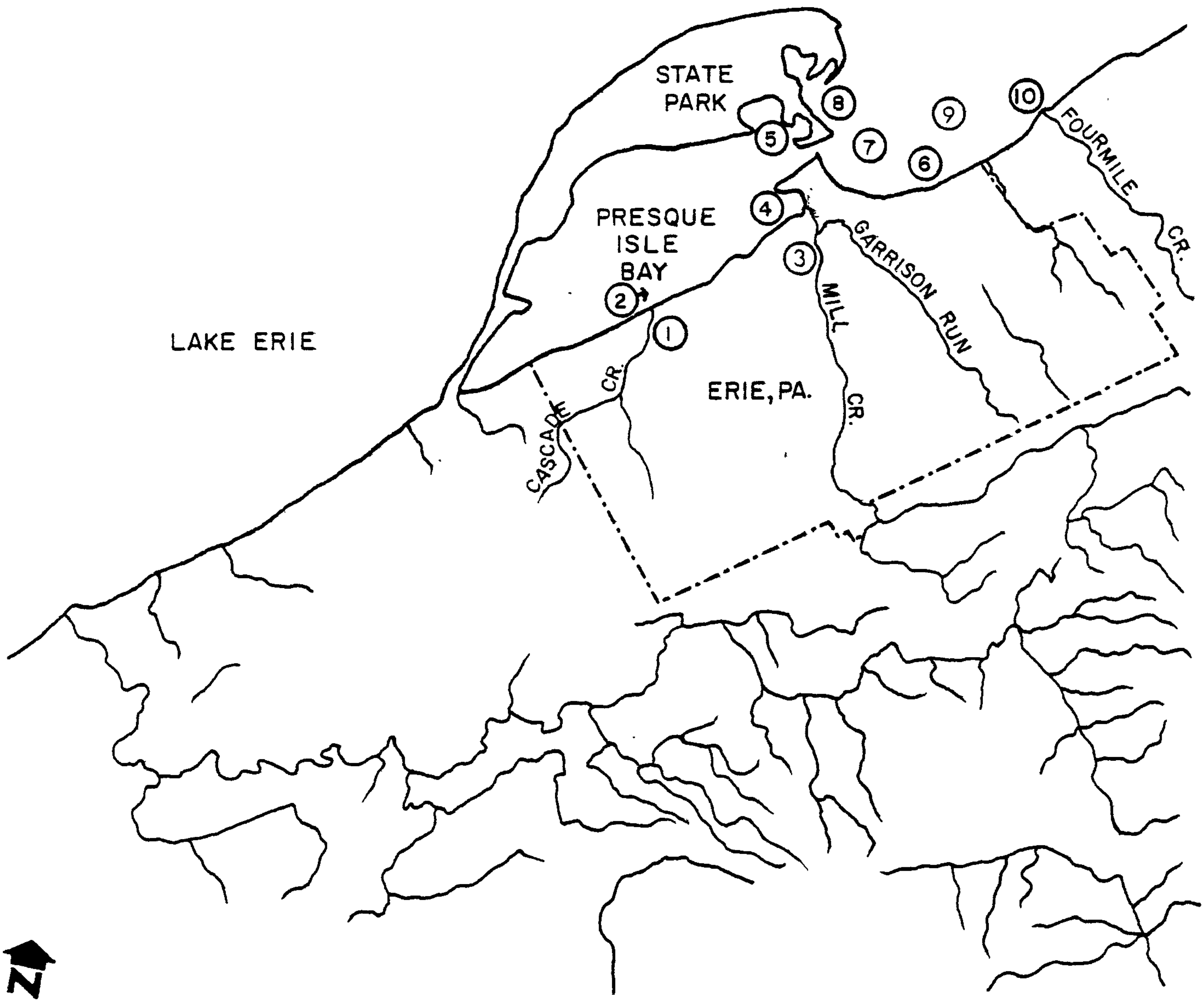


FIGURE 5

LOCATION OF PRIMARY SAMPLING STATIONS

Station 9 - Lake Erie in vicinity of City of Erie and Hammermill Paper Company discharges.

Station 10 - Lake Erie about 200 feet north of the confluence of Fourmile Creek and Lake Erie.

Stations 1 and 3, located on Cascade Creek and Mill Creek respectively, were selected to provide water quality data on the tributary input to Presque Isle Bay. Past water quality studies (Great Lakes Research Institute, 1972, 1973) did not measure the water quality of these tributary streams. However, in their 1973 report, the Great Lakes Research Institute recommended that the tributary streams be included in the monitoring program sponsored by the Erie County Health Department.

Additional stream samples were collected on Cascade Creek (Station 1) at various upstream locations to further locate possible sources of stream pollution. These additional stations were sampled selectively three times during the study. Garrison Run, another tributary stream that combined with Mill Creek below the Erie Wastewater treatment Plant, was also sampled three times during the study to further define the water quality entering Presque Isle Bay.

Stations 2 and 4, located in Presque Isle Bay offshore of Cascade and Mill Creeks respectively, were selected to determine whether the water quality in the vicinity of the tributaries was significantly different than that in the rest of the bay.

Station 5, located in Misery Bay was selected to provide a measure of the water quality in the bay at a point relatively unaffected by localized industrial and municipal discharges. In their 1972 report, Aquatic Ecology Associates indicated that Misery Bay contained the most diverse biological habitat.

Station 6, located offshore of Hammermill Paper Company was selected to determine the localized effects of wastewater discharges from Hammermill Paper Company. Station 7, located east of the channel, was selected to measure the water quality just outside of the bay. It was also measured to provide the baseline water quality of this area prior to proposed Corps of Engineers dredge and fill operations in adjacent areas.

Station 8, located about 300 feet offshore of Beach 11, was selected to provide a measure of the existing water quality off Beach 11, an important recreational beach. Personnel of the Erie Counth Health Department have communicated concern over the effects of proposed Corps of Engineers dredging on the water quality at Beach 11. The Corps of Engineers plan to dredge and fill a portion of the outer bay. Specifically, plans exist for the filling in of the area west of Station 7 with dredge material to increase the land area north of the wastewater treatment plant.

Station 9, located in the vicinity of the City of Erie and Hammermill Paper Company wastewater dischargers, was selected to measure the effects these discharges have on the lake water quality.

Station 10, located about 200 feet offshore of the confluence of Fourmile Creek and Lake Erie, was selected to measure the downstream extent of industrial and municipal discharges. Prevailing lake currents tend to push the lake water in a southeasterly direction, keeping much of the wastewater discharges near the south shore of Lake Erie.

Additional stations were sampled selectively during the study to measure localized water quality conditions that were observed in the field. Such stations usually concentrated on areas adjacent to the confluence of Mill Creek and areas adjacent to Hammermill Paper Company (see Figure 6).

Other water quality studies have been performed in the Presque Isle Bay area. Gottschall and Jennings performed limnological studies at Erie, Pennsylvania in 1933 with major emphasis on the phytoplankton. In 1970, Zagorski and O'Tool studied the phytoplankton and zooplankton at four locations within the bay. The Pennsylvania Fish Commission has occasionally collected fishery data within the bay (Aquatic Ecology Associates, 1973). In 1972 and 1973, the Great Lakes Research Institute performed studies of the bay and lake areas. Three stations were samples in 1972 and seven stations were sampled in 1973. These studies, performed for the Erie County Health Department are expected to be continued. In 1972, Aquatic Ecology Associates investigated the ecological condition of Presque Isle Bay for the Pennsylvania Electric Company. Other studies of the area have been performed by local universities. For a complete account of all past studies, refer to the Comprehensive Waste and Water Quality Management Study (Engineering Science, 1974).

For ease of understanding, a summary of the organization of this section is presented below:

Presque Isle Bay and Lake Stations
Stream stations
Sediment Analyses
Bacteria
Plankton
Discussion

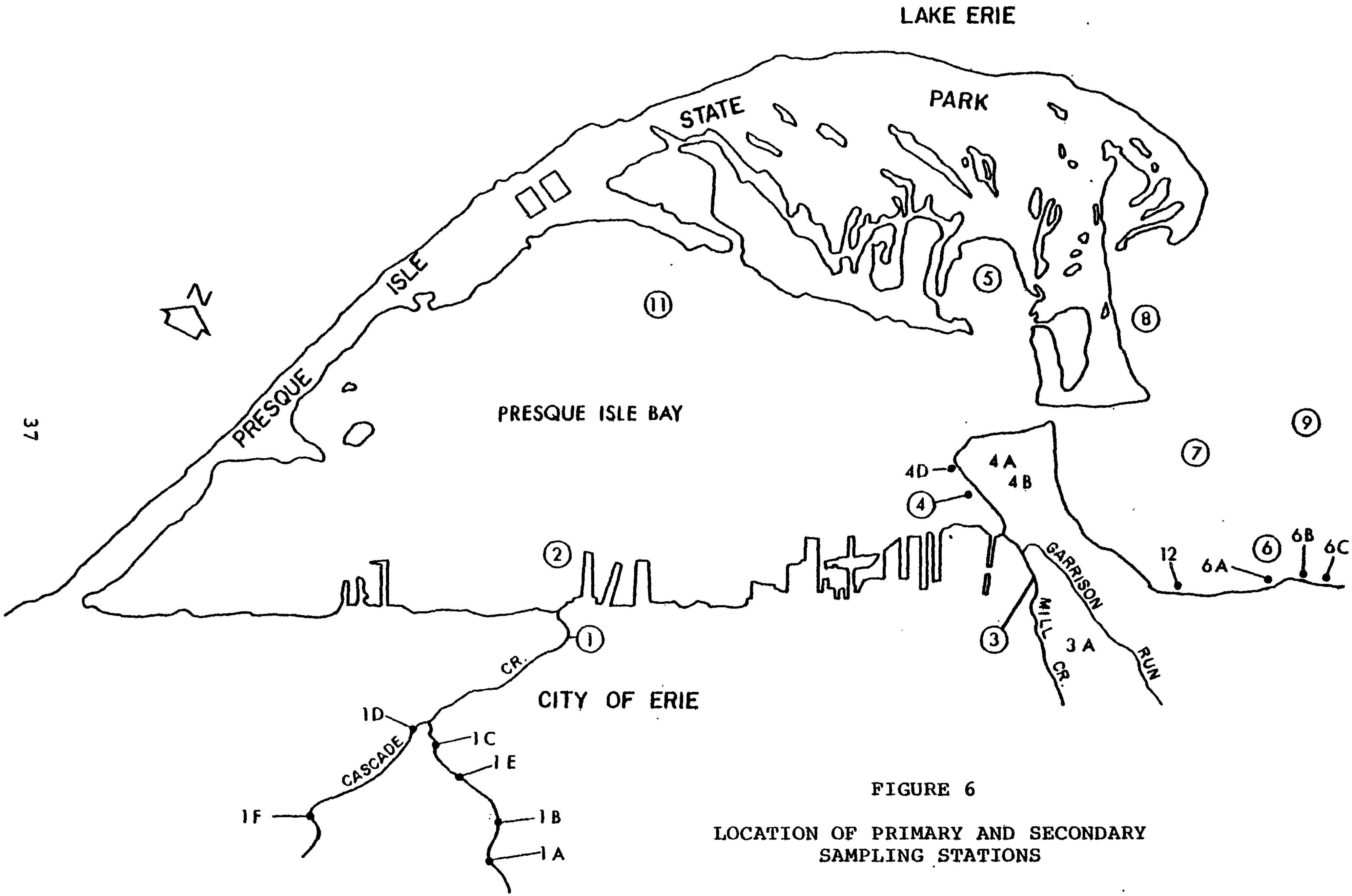


FIGURE 6

LOCATION OF PRIMARY AND SECONDARY SAMPLING STATIONS

In this report, "bay" stations refer to those stations located in Presque Isle Bay and "lake" stations refer to those located in Erie Harbor and Lake Erie.

During each survey, water samples were collected from one foot below the surface and placed into special containers for chemical and biological analyses. Water samples for nutrient analyses were preserved with mercuric chloride and samples for metal analyses were preserved with nitric acid. All samples were preserved in accordance with methods approved by the U. S. Environmental Protection Agency. For phytoplankton analyses, five liters of water were filtered through a Wisconsin style plankton net, and the concentrated plankton samples were preserved with formalin. The plankton net was made of No. 20 silk bolting cloth and as such measured only net plankton. Nannoplankton was not measured in this study. Samples for biochemical oxygen demand (BOD) were collected in sterilized glass bottles and preserved in ice.

Samples to be analyzed for general chemical analyses such as nutrients and metals were sent to the EPA field laboratory in Charlottesville, Virginia to be analyzed by EPA personnel. All analyses were performed in accordance with the 1971 edition of "Methods for Chemical Analysis of Water and Wastes" (U.S. Environmental Protection Agency, 1971). Nutrient analyses were performed on the autoanalyzer; metals were measured on the atomic absorption spectrophotometer. Bacteriological and BOD samples were taken to the Church Laboratory and Betz Laboratories, Inc., to check on the quality control of Church Laboratory. Good agreement was obtained for fecal coliform, total coliform and BOD. Samples for plankton analyses were transported to Betz Laboratories, Inc., for analysis. Samples collected during the June survey were sent to Betz Laboratories for the chemical analyses rather than to the EPA Charlottesville Laboratory because of project time constraints. All samples were analyzed according to procedures promulgated or approved by the U.S. Environmental Protection Agency.

Temperature and dissolved oxygen measurements were taken in situ using a YSI dissolved oxygen probe. During the June survey, samples were collected at three depths: surface, mid-depth and bottom. These samples were collected to ascertain the degree of vertical mixing occurring during the spring to summer transition period. Although maximum summer stratification would be expected in July or August, project time constraints did not allow the sampling program to proceed beyond June.

Sediment samples were collected at six stations on June 4 and 5, 1974 to determine the chemical composition at various bay and lake locations.

Physical and Chemical Characteristics

Presque Isle Bay and Lake Stations

Results of the physical and chemical analyses of Presque Isle Bay and Erie Harbor stations are presented in Appendix A. A summary of mean and range values for chemical parameters is presented in Table 6. Where appropriate, chemical parameters are related to Pennsylvania Water Quality Standards (U.S. Environmental Protection Agency, 1974; State of Pennsylvania, 1973).

Nitrogen

Ammonia levels in Presque Isle Bay were generally higher than at the lake stations (Table 6), with the exception of Station 9 which was located in the vicinity of the wastewater discharges from the City of Erie and Hammermill Paper Company. Only one sample, located at Station 9, exceeded the allowable limit of 0.5 mg/l set for surface water for public water supplies. A general water quality criteria for ammonia has not been set for Presque Isle Bay and Erie Harbor. The high average ammonia concentration at Station 9 (0.16 mg/l) along with the highest ammonia concentration measured during the study (0.51 mg/l) indicates that either Hammermill Paper Company or the City of Erie is discharging significant amounts of ammonia. Analyses of the Hammermill Paper Company's pulp bleaching wash waters, which discharge in the vicinity of Station 9, indicate that a free ammonia concentration of about 3 mg/l is discharged. Waste inspection records of the Erie County Health Department indicate that the Hammermill paper mill screening effluent, which discharges to Motch Run and thence to Lake Erie, contains an ammonia concentration of 7.8 mg/l. In addition, a significant contribution to the ambient ammonia concentrations observed is being provided by the treated wastewater from the City of Erie sewage treatment plant. The effluent from the City of Erie sewage treatment plant contains an ammonia concentration of 11 mg/l (Engineering - Science, 1974).

The mean ammonia concentration was highest at Station 2 (0.17 mg/l) with Station 9 (0.16 mg/l) a very close second. At Station 2, located in Presque Isle Bay directly out from the confluence of Cascade Creek with the bay, ammonia concentrations ranged from 0.04 to 0.32 mg/l, indicating that Cascade Creek is a major source of ammonia contamination. Station 1, located on Cascade Creek just upstream of its confluence with the bay, had a mean ammonia concentration of 1.51 mg/l and a range of 0.10 to 5.88 mg/l. These high ammonia concentrations clearly indicate that Cascade Creek is (1) receiving discharges high in ammonia, (2) significantly con-

TABLE 6

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 2 Mean	Range
pH	7.8	7.4-8.0
Alkalinity mg/l	95	92-108
Color Units	6	3-10
Total Solids mg/l	206	172-230
Suspended Solids mg/l	5	2-8
Biological Oxygen Demand mg/l	5.4	2.0-10.0
Ammonia as N mg/l	0.17	0.04-0.32
Nitrite as N mg/l	0.05	0.01-0.18
Nitrate as N mg/l	0.31	0.04-0.90
Organic Nitrogen as N mg/l	0.45	0.01-1.68
Total Kjeldahl Nitrogen as N mg/l	0.63	0.06-2.00
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.03	0.00-0.07
Total Phosphorus as P mg/l	0.08	0.02-0.17
Total Organic Carbon mg/l	9	0-11
Iron as Fe ug/l	390	100-734
Copper as Cu ug/l	6	1-15
Lead as Pb ug/l	9	6-13
Zinc as Zn ug/l	20	0-53
Cadmium as Cd ug/l	3.6	0.01-10
Chromium as Cr ug/l	26	0.69
Aluminum as Al ug/l	282	120-407
Mercury as Hg ug/l	3	0.1-8.3

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 4 Mean	Range
pH	7.7	7.2-8.1
Alkalinity mg/l	96	93-104
Color Units	8	1-15
Total Solids mg/l	215	198-240
Suspended Solids mg/l	6	4-8
Biological Oxygen Demand mg/l	7.3	1.0-12.0
Ammonia as N mg/l	0.13	0.03-0.31
Nitrite as N mg/l	0.05	0.01-0.13
Nitrate as N mg/l	0.51	0.02-1.60
Organic Nitrogen as N mg/l	0.15	0.06-0.25
Total Kjeldahl Nitrogen as N mg/l	0.27	0.11-0.56
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.04	0.01-0.07
Total Phosphorus as P mg/l	0.07	0.02-0.13
Total Organic Carbon mg/l	10	0-13
Iron as Fe ug/l	315	100-464
Copper as Cu ug/l	4	0-134
Lead as Pb ug/l	7	2-12
Zinc as Zn ug/l	18	0.65
Cadmium as Cd ug/l	3.7	0.01-10
Chromium as Cr ug/l	31	0-74
Aluminum as Al ug/l	256	180-318
Mercury as Hg ug/l	3	0.1-8.3

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 5 Mean	Range
pH	7.8	7.3-8.1
Alkalinity mg/l	95	91-106
Color Units	8	5-15
Total Solids mg/l	208	196-230
Suspended Solids mg/l	6	5-8
Biological Oxygen Demand mg/l	6.6	4.0-11.0
Ammonia as N mg/l	0.13	0.01-0.22
Nitrite as N mg/l	0.05	0.01-0.18
Nitrate as N mg/l	0.34	0.01-0.90
Organic Nitrogen as N mg/l	0.62	0.06-2.25
Total Kjeldahl Nitrogen as N mg/l	0.71	0.06-2.40
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.03
Total Dissolved Phosphorus as P mg/l	0.05	0.01-0.18
Total Phosphorus as P mg/l	0.07	0.02-0.19
Total Organic Carbon mg/l	9	0-11
Iron as Fe ug/l	248	198-398
Copper as Cu ug/l	2	0-7
Lead as Pb ug/l	9	2-22
Zinc as Zn ug/l	7	0-20
Cadmium as Cd ug/l	4.6	0.01-13
Chromium as Cr ug/l	16	0-41
Aluminum as Al ug/l	191	114-291
Mercury as Hg ug/l	3	0.1-6.7

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 6 Mean	Range
pH	7.6	7.2-7.9
Alkalinity mg/l	114	90-122
Color Units	9	5-15
Total Solids mg/l	224	193-266
Suspended Solids mg/l	8	4-12
Biological Oxygen Demand mg/l	12.8	2.0-36.0
Ammonia as N mg/l	0.08	0.02-0.22
Nitrite as N mg/l	0.05	0.01-0.19
Nitrate as N mg/l	0.54	0.02-1.60
Organic Nitrogen as N mg/l	0.19	0.04-0.35
Total Kjeldahl Nitrogen as N mg/l	0.28	0.06-0.53
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.01
Total Dissolved Phosphorus as P mg/l	0.03	0.00-0.08
Total Phosphorus as P mg/l	0.07	0.02-0.17
Total Organic Carbon mg/l	15	0-20
Iron as Fe ug/l	409	200-820
Copper as Cu ug/l	3	0-6
Lead as Pb ug/l	7	2-14
Zinc as Zn ug/l	5	0-10
Cadmium as Cd ug/l	3.1	0.01-10
Chromium as Cr ug/l	12	0-40
Aluminum as Al ug/l	389	235-640
Mercury as Hg ug/l	4	0.1-10.4

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 7 Mean	Station 7 Range
pH	7.7	7.1-8.0
Alkalinity mg/l	107	87-188
Color Units	7	3-15
Total Solids mg/l	200	189-210
Suspended Solids mg/l	7	5-10
Biological Oxygen Demand mg/l	6.0	0-17.0
Ammonia as N mg/l	0.08	0.01-0.27
Nitrite as N mg/l	0.08	0.01-0.33
Nitrate as N mg/l	0.31	0.01-1.30
Organic Nitrogen as N mg/l	0.21	0.05-0.40
Total Kjeldahl Nitrogen as N mg/l	0.29	0.05-0.57
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.02	0.00-0.04
Total Phosphorus as P mg/l	0.08	0.02-0.23
Total Organic Carbon mg/l	9	0-11
Iron as Fe ug/l	317	100-564
Copper as Cu ug/l	4	018
Lead as Pb ug/l	8	2-16
Zinc as Zn ug/l	13	0-52
Cadmium as Cd ug/l	3.0	0.02-10
Chromium as Cr ug/l	9	0-24
Aluminum as Al ug/l	305	150-490
Mercury as Hg ug/l	2	0.1-7.4

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 8 Mean	Range
pH	7.8	7.2-8.0
Alkalinity mg/l	106	87-188
Color Units	5	2-10
Total Solids mg/l	200	187-217
Suspended Solids mg/l	7	4-10
Biological Oxygen Demand mg/l	8.0	2.0-21.0
Ammonia as N mg/l	0.09	0.01-0.30
Nitrite as N mg/l	0.05	0.01-0.20
Nitrate as N mg/l	0.54	0.01-1.71
Organic Nitrogen as N mg/l	0.19	0.04-0.42
Total Kjeldahl Nitrogen as N mg/l	0.28	0.04-0.72
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.03	0.00-0.11
Total Phosphorus as P mg/l	0.08	0.02-0.20
Total Organic Carbon mg/l	9	0-11
Iron as Fe ug/l	309	100-518
Copper as Cu ug/l	3	0-9
Lead as Pb ug/l	7	2-12
Zinc as Zn ug/l	13	0-40
Cadmium as Cd ug/l	3.0	0.01-10
Chromium as Cr ug/l	12	0-56
Aluminum as Al ug/l	343	50-645
Mercury as Hg ug/l	1	0.1-3.4

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 9 Mean	Station 9 Range
pH	7.6	7.1-8.0
Alkalinity mg/l	109	87-188
Color Units	6	4-10
Total Solids mg/l	198	187-207
Suspended Solids mg/l	6	4-10
Biological Oxygen Demand mg/l	6.6	2.0-15.0
Ammonia as N mg/l	0.16	0.03-0.51
Nitrite as N mg/l	0.05	0.01-0.15
Nitrate as N mg/l	0.48	0.02-1.10
Organic Nitrogen as N mg/l	0.16	0.03-0.33
Total Kjeldahl Nitrogen as N mg/l	0.34	0.11-0.84
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.02	0.00-0.03
Total Phosphorus as P mg/l	0.09	0.02-0.20
Total Organic Carbon mg/l	10	0-12
Iron as Fe ug/l	283	100-614
Copper as Cu ug/l	2	0-8
Lead as Pb ug/l	8	2-21
Zinc as Zn ug/l	4	0-12
Cadmium as Cd ug/l	2.7	0.02-10
Chromium as Cr ug/l	20	0-54
Aluminum as Al ug/l	236	50-477
Mercury as Hg ug/l	2	0.1-3.8

TABLE 6 (cont'd)

SUMMARY DATA FOR LAKE STATIONS

CONSTITUENTS	Station 10 Mean	Range
pH	7.6	7.1-7.9
Alkalinity mg/l	114	91-186
Color Units	35	30-40
Total Solids mg/l	237	213-298
Suspended Solids mg/l	11	3-17
Biological Oxygen Demand mg/l	10.4	5.0-14.0
Ammonia as N mg/l	0.08	0.01-0.28
Nitrite as N mg/l	0.08	0.01-0.24
Nitrate as N mg/l	0.49	0.01-1.30
Organic Nitrogen as N mg/l	0.48	0.05-1.19
Total Kjeldahl Nitrogen as N mg/l	0.57	0.05-1.47
Dissolved Orthophosphate as P mg/l	0.01	0.00-0.02
Total Dissolved Phosphorus as P mg/l	0.02	0.00-0.03
Total Phosphorus as P mg/l	0.07	0.02-0.20
Total Organic Carbon mg/l	17	0-21
Iron as Fe ug/l	334	120-580
Copper as Cu ug/l	3	0-9
Lead as Pb ug/l	8	2-18
Zinc as Zn ug/l	14	0-39
Cadmium as Cd ug/l	2.9	0.02-10
Chromium as Cr ug/l	10	0-32
Aluminum as Al ug/l	469	160-930
Mercury as Hg ug/l	4	0.1-8.9

tributing to the ammonia content of the bay, and (3) exceeding the water quality criteria of 1.5 mg/l (from 6/1 to 10/31) and 4.5 mg/l (from 11/1 to 5/31) set for this stream.

A similar situation was observed at Station 4, located opposite the confluence of Mill Creek and Presque Isle Bay. Relatively high ammonia concentrations were found, ranging from 0.03 to 0.31 mg/l with an average of 0.13 mg/l. Station 3, located on Mill Creek just upstream from Station 4, had ammonia concentrations ranging from 0.14 to 8.40 mg/l and an average of 2.74 mg/l. These results indicate that the high ammonia concentrations observed at Station 4 are caused by the large influx of ammonia from Mill Creek.

Nitrate concentrations showed a greater variation over time than between stations. Levels were lowest in the fall and increased in the winter at all stations. In the bay, nitrate concentrations were highest in December, while at the lake stations, peak concentrations occurred in May. This seasonal pattern in nitrate levels is generally associated with plankton levels. As plankton numbers decline, nitrates are released, increasing the nitrate concentration in the water. Nitrate levels then decrease in the summer when plankton populations increase.

Both organic and Kjeldahl nitrogen concentrations were highest at Stations 2, 5 and 10. High concentrations of Kjeldahl nitrogen were found in Cascade Creek (Station 1) and account for the high Kjeldahl nitrogen levels found in the bay at Station 2. However, Mill Creek (Station 3) had even higher Kjeldahl nitrogen levels than Cascade Creek yet Station 4, located in the bay at the Mill Creek confluence, had relatively low Kjeldahl nitrogen concentrations. High nitrogen concentrations at Station 5, located in Misery Bay, could be a result of either the discharge of organic materials and nutrients from the marsh areas in Presque Isle State Park or the accumulation of organic and nutrient material transported to Misery Bay by bay and lake currents. The high nitrogen levels found at Station 10, located offshore from Fourmile Creek may be a result of wastewater from Hammermill Paper Company.

Besides having high organic and Kjeldahl nitrogen levels, Stations 2, 5 and 10 had relatively low nitrate levels, indicating the presence of unoxidized organic matter in these areas. In contrast, Stations 4, 6, 8 and 9 had the lowest mean organic and Kjeldahl nitrogen concentrations and comparatively high nitrate levels. Total nitrogen levels were generally highest in May, probably resulting from the unstratified, completely-mixed nature of the lake in spring.

Phosphorus

Mean Total phosphorus concentrations were relatively similar for all bay and lake stations and ranged from 0.07 mg/l to 0.09 mg/l. At most stations maximum total phosphorus concentrations occurred in June. Orthophosphate concentrations were generally below 0.01 mg/l as phosphorus with exceptions occurring primarily in the winter and early spring. Orthophosphate, like nitrate, is closely associated with plankton growth. Orthophosphate is tied up in plankton biomass in the summer and is released as the organisms die off in late fall. The relatively low phosphorus levels in the bay and lake area indicate that phosphorus is being utilized in phytoplankton growth. Consideration of the relatively high phosphorus concentrations entering the bay from Cascade Creek (average phosphorus concentration of 0.14 mg/l) and Mill Creek (average phosphorus level of 1.12 mg/l) further strenghtens the concept that phosphorus is being rapidly utilized by the phytoplankton. Water quality criteria for Erie Harbor and Presque Isle Bay do not specify a numerical phosphorus limitation. The criteria for Lake Erie indicate that phosphorus concentrations should be limited to prevent nuisance growths of algae, weeds and slimes.

Total Organic Carbon

Total organic carbon is a measure of the carbon tied up in living and dead organic materials. Total organic carbon mean values were 9-10 mg/l at all stations except Stations 6 and 10 where mean values were 15 mg/l and 17 mg/l respectively. Organic carbon concentrations ranged from 0 to 21 mg/l for individual sampling dates, but exhibited no observable seasonal pattern. There is no water quality criterion for total organic carbon. The high organic carbon levels measured at Stations 6 and 10, located adjacent to and downstream of Hammermill Paper Company, are probably caused by the discharge of paper mill wastes by Hammermill. During all sampling dates, highly colored water was observed in the vicinity of Station 10. This color could be traced back to the Hammermill discharge. To further investigate the source of color and high organic carbon, an additional sampling station, Station 6A, was established at a distance of about 100 feet offshore from the Hammermill Paper Company. The total organic carbon concentration measured at this station was 24 mg/l, a value higher than that found at either Station 6 or Station 10. This high organic carbon content indicates that the source of organic carbon found at stations 6 and 10 is the Hammermill Paper Company wastewater discharge. Thus, the high organic carbon levels appear to be caused by organic plant materials discharged by the Hammermill Paper Company.

Biochemical Oxygen Demand

The biochemical oxygen demand (BOD) is the amount of oxygen utilized by microorganisms to oxidize complex organic matter to relatively stable organic compounds. It is a measure of the amount of biodegradable organic material present in a water. The biochemical oxygen demand measured in the bay and lake water was high for lake water. However, no water quality criterion for BOD has been promulgated for these waters. Considering all of the bay and lake stations, peak BOD values ranging from 10 to 21 mg/l occurred in October. Maximum individual BOD values, however, occurred at Stations 4A, 6 and 6A. Station 4A, located about 200 feet out from the Mill Creek confluence, was added to the study to determine the effects of Mill Creek on the local environment of the bay and to measure the mixing characteristics of Mill Creek water with bay water. The maximum BOD measured in the bay and lake areas, a BOD of 70 mg/l, occurred at Station 4A. This extremely high BOD was caused by low quality water entering the bay from Mill Creek. On the same day that this high BOD was measured, a maximum stream BOD of 120 mg/l was measured in Mill Creek, a short distance upstream of Station 4A. Thus, the high biochemical oxygen demand observed at Station 4A was directly caused by the influx of poor quality water from Mill Creek.

The high BOD values measured at Stations 6 and 6A, like the organic carbon levels, appear to be caused by the Hammermill Paper Company's wastewater discharges.

Total and Suspended Solids

Total solids concentrations in the bay and lake areas ranged from 172 to 379 mg/l with the maximum concentration occurring at Station 6A, located about 100 feet offshore from the Hammermill Paper Company. Total dissolved solids were well under the established criterion of 500 mg/l. Suspended solids concentrations ranged from 2 to 108 mg/l with an average value of about 7 mg/l. The maximum suspended solids concentration of 108 mg/l occurred at Station 4A. Suspended solids at Station 4A were always greater then the average suspended solids in the bay and lake areas, ranging from 24 to 108 mg/l. Station 10, located downstream of the Hammermill Paper Company, also had relatively high suspended solids concentrations ranging from 3 to 17 mg/l and averaging 11 mg/l. Station 4A, located about 200 feet offshore from the Mill Creek confluence, had a suspended solids concentration of 18 mg/l, indicating the effect of Mill Creek on local water quality.

pH and Alkalinity

The pH values ranged from 6.9 to 8.1 and appeared to show a seasonal pattern. Values were highest in the fall, decreased in the winter, and began increasing again in the spring. This pattern corresponds to the cyclic nature of algae populations. As phytoplankton levels increase, carbon dixoide is removed from the water for photosynthesis and this process causes an increase in the pH. Conversely, bacterial decomposition removes oxygen and adds carbon dioxide to the water, causing a decrease in pH. This effect is illustrated at Station 4A, located offshore from the Mill Creek confluence and downstream of the City of Erie sewage treatment plant. A pH of 6.9, the lowest pH measured in the bay and lake areas, was measured at this station.

Pennsylvania water quality criteria specify a pH between 6.0 and 9.0 for Erie Harbor and Presque Isle Bay and a pH between 6.7 and 8.5 for Lake Erie. All stations were within the specified limits indicating the water is adequately buffered and free of excessive acidic and alkaline materials.

Alkalinity, a measure of the buffer capacity of a natural water, is caused primarily by carbonate and bicarbonate salts in solution. The alkalinity of a natural water acts as a carbon reservoir for algae production. Algae utilize carbon dioxide as a carbon source in the process of photosynthesis to produce organic matter (more algae) and oxygen. In a natural water, an equilibrium exists between carbon dioxide, carbonate and bicarbonate, and, as the carbon dioxide is used up by photosynthetic activity, more carbon dioxide is produced from the carbonate and bicaronate forms of alkalinity by a shift in the equilibrium as shown below:

$$2HCO_3^- = CO_3^= + H_2O + CO_2$$

$$CO_3^= + H_2O = 2OH^- + CO_2$$

The increase in pH associated with algal production is caused by the addition of hydroxide ions to the water. Thus, alkalinity is directly related to the productivity of a natural water.

Alkalinities in the bay and lake areas ranged from 92 to 222 mg/l with an average of about 100 mg/l. Peak alkalinities occurred in June. The maximum alkalinity occurred at Station 6, offshore from the Mill Creek confluence. In the pH range found in these waters (6.9 to 8.1), most of the alkalinity would be bicarbonate.

Color

In general, color in the bay and lake areas was low with the exception of Stations 6A and 10. As noted above, these stations are adjacent to and downstream of Hammermill Paper Company respectively. Color at Station 6A ranged from 12 to 65 units (1 unit = 1 mg/l platinum as chloroplatinate ion) while at Station 10 color ranged from 30 to 40 units. During each survey, a brown color was observed at Station 10; this color could be traced back to the Hammermill Paper Company's discharge which was also brown in color. The high color levels observed at Stations 6A and 10 correlate with the high organic carbon and BOD values observed. An additional station, Station 12, was sampled during the June survey to determine the extent of the color in the lake. Station 12 was located upstream of Hammermill, opposite the Koppers Company plant (formerly Interlake Steel). At Station 12, both the color and suspended solids were high with values of 25 units and 20 mg/l respectively. The Koppers discharge, however, consisting of process cooling water, was hot, but did not contain high color or suspended solids. Thus, the high color observed at Station 12 appears to be caused by the Hammermill Paper Company. Easterly winds evidently produce upstream currents that transport pollutants towards the bay area.

Heavy Metals

Within station variations over time were greater than between station differences for all heavy metals measured. Heavy metal levels were generally well within detectable limits. Higher than average concentrations of various heavy metals were found at different stations as summarized below.

Station	High Heavy Metal Concentrations
2	Chromium
4	Copper, Zinc
4A	Iron, Copper, Zinc, Lead & Cadmium
5	Lead
6	Iron and Copper
6A	Iron, Zinc, Copper and Aluminum

Stations 2, 4 and 4A indicate the effect of Cascade and Mill Creeks on the receiving water. Stations 6 and 6A, located opposite Hammermill Paper Company, indicate possible heavy metal contamination. Station 5, located in Misery Bay, indicates some lead contamination from the Presque Isle swamps or from bay currents transporting materials to Misery Bay. Pennsylvania water quality standards indicate that dissolved iron should not exceed 0.3 mg/l. Since only total iron was measured, it is not possible to determine whether the standard was exceeded. However, in the lake water, total iron concentration ranged from 0.1 to 0.8 mg/l, indicating a strong possibility that the standard might have been exceeded.

Temperature and Dissolved Oxygen

Temperatures in the bay area were slightly higher than those in the lake. Most temperatures, however, were similar at most stations indicating that the bay and lake were relatively well-mixed and homogeneous. Higher than average temperatures were found at Staions 4A and 4B, located near the Mill Creek confluence. These higher temperatures reflect the effect of Mill Creek and its sewage contaminated water on the lake area adjacent to the creek's discharge point. High temperatures were also observed in the cooling water discharge from the Koppers Company, at Station 10, at the General Electric outfall and near the water intake from Pennelec (Pennsylvania Electric Company).

Dissolved oxygen levels in the bay and lake areas were relatively high throughout the study period, ranging from about 8 mg/l in the fall to about 10 mg/l in the spring. In September, oxygen values ranged from 82 to 90 percent saturation. In October, oxygen values ranged from 60 to 107 percent saturation. However, Stations 6A, 6B and 6C, located offshore from Hammermill Paper Company, ranged from 51 to 64 percent saturation. Stations 4A and 4B, located directly out from the Mill Creek confluence, ranged from 7 to 28 percent saturation, indicating the effect of organic pollution in Mill Creek. In May of 1974, oxygen values ranged from 84 to 108 percent saturation; and in June, values ranged from 63 to 124 percent saturation for surface waters and from 47 to 110 percent saturation for bottom waters. Very little changes were observed in oxygen levels from October through June. In October a diurnal dissolved oxygen survey was performed to determine day and night variations in oxygen levels. Small diurnal changes were observed in both the bay and lake. For example, at Station 2 the dissolved oxygen ranged from 9.6 to 10.8 mg/l (91 to 104 percent saturation) over a 24-hour period. At Station 5, the DO range over 24 hours was 9.6 to 10.5 mg/l (55 to 103 percent saturation).

In general, Stations 6 and 10 had the lowest dissolved oxygen concentrations of all the regular stations, indicating the possible influence of Hammermill's wastewater discharge. Stations 6A, 6B and 6C, located adjacent to the Hammermill Paper Company, had dissolved oxygen concentrations of 6.5, 5.9 and 4.8 mg/l respectively, indicating depressed oxygen conditions in the vicinity of the Hammermill discharge.

Low oxygen levels were also found at Stations 4A, 4B and 4D, located near the Mill Creek confluence. At Station 4A, dissolved oxygen levels ranged from 0.7 to 8.1 mg/l with most concentrations below 3 mg/l.

The Pennsylvania water quality criteria for dissolved oxygen is that the minimum daily average be 5.0 mg/l or greater and that no value should be less than 4.0 mg/l. Localized areas around the confluence of Mill Creek (Stations 4A, 4B and 4D) and offshore from Hammermill Paper Company (Station 6C) do not meet these criteria. All other areas studied were well above these criteria. High dissolved oxygen levels were consistent at Station 5, located in Misery Bay, reflecting the highly productive nature of the water in this area. Temperature and dissolved oxygen versus depth curves are presented in Figure 7.

Transparency

Secchi disc reading, a measure of transparency, was relatively constant throughout the study period, averaging about 1.3 meters. Low Secchi disc readings were found at Stations 4A, 4B, 6, 6A, 6B and 6C. These low readings reflect the general poor water quality observed at these stations. At Stations 4A and 4B, downstream of the sewage treatment plant, the low transparency was due to suspended solids. At Stations 6, 6A, 6B and 6C, located adjacent to the Hammermill Paper Company, the low transparency was due to color and suspended solids. A low reading was also found at the bay area adjacent to Pennelec and the northwest Marina.

Stream Stations

Cascade Creek

Cascade Creek drains the western section of the City of Erie. It originates in a degraded area of the city in a swampy area used as a junk disposal area by individuals and commercial establishments. Cascade Creek flows roughly from 28th Street to the bay, passing through areas dominated by small industries and commercial establishments. Storm drains and other discharges appear to flow into Cascade Creek. Cascade Creek is made up of a west and an east branch. The east branch is the main stem and flows from about 28th Street to the bay. The west branch combines with the east branch just below 8th Street. From West Third Street to the bay, Cascade Creek passes through a heavily industrialized area containing the following industries:

Allied Oil Company, Inc.
United Oil Manufacturing Company
Perry Shipbuilding Company

Summary data of means and ranges for Cascade Creek are pre-

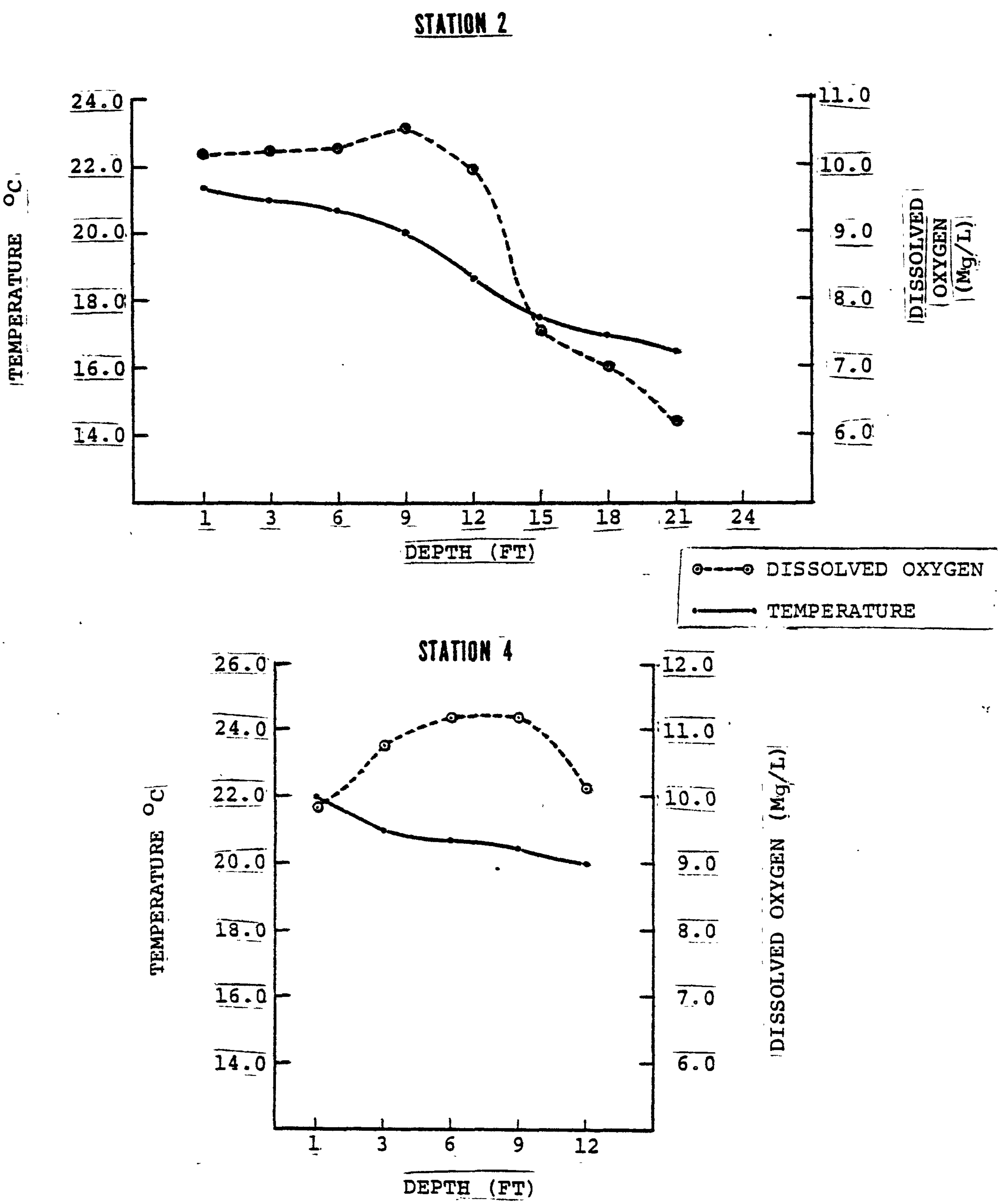


Figure 7

TEMPERATURE AND DISSOLVED OXYGEN PROFILE

June 4-5, 1974

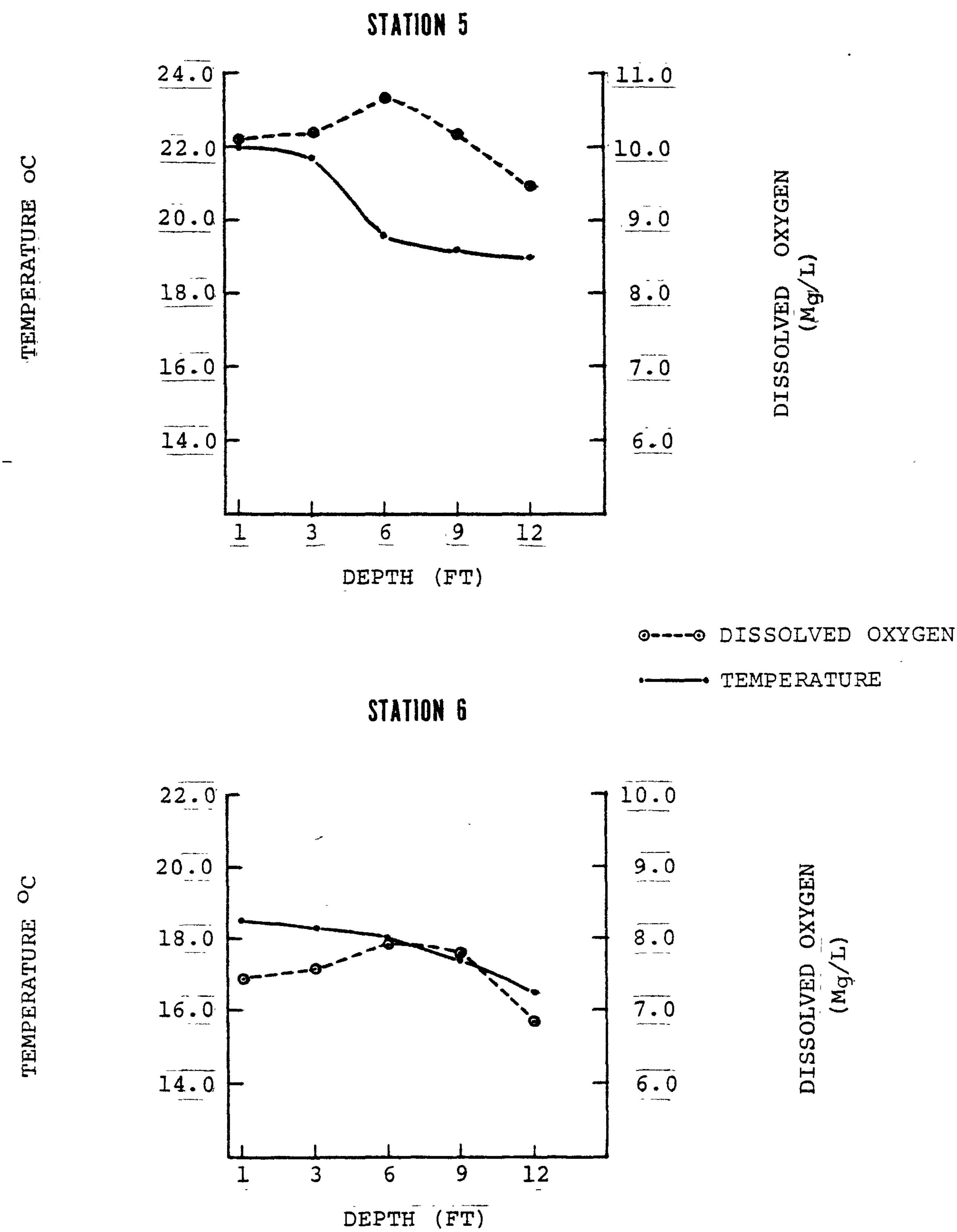


Figure 7

TEMPERATURE AND DISSOLVED OXYGEN PROFILE

June 4-5, 1974

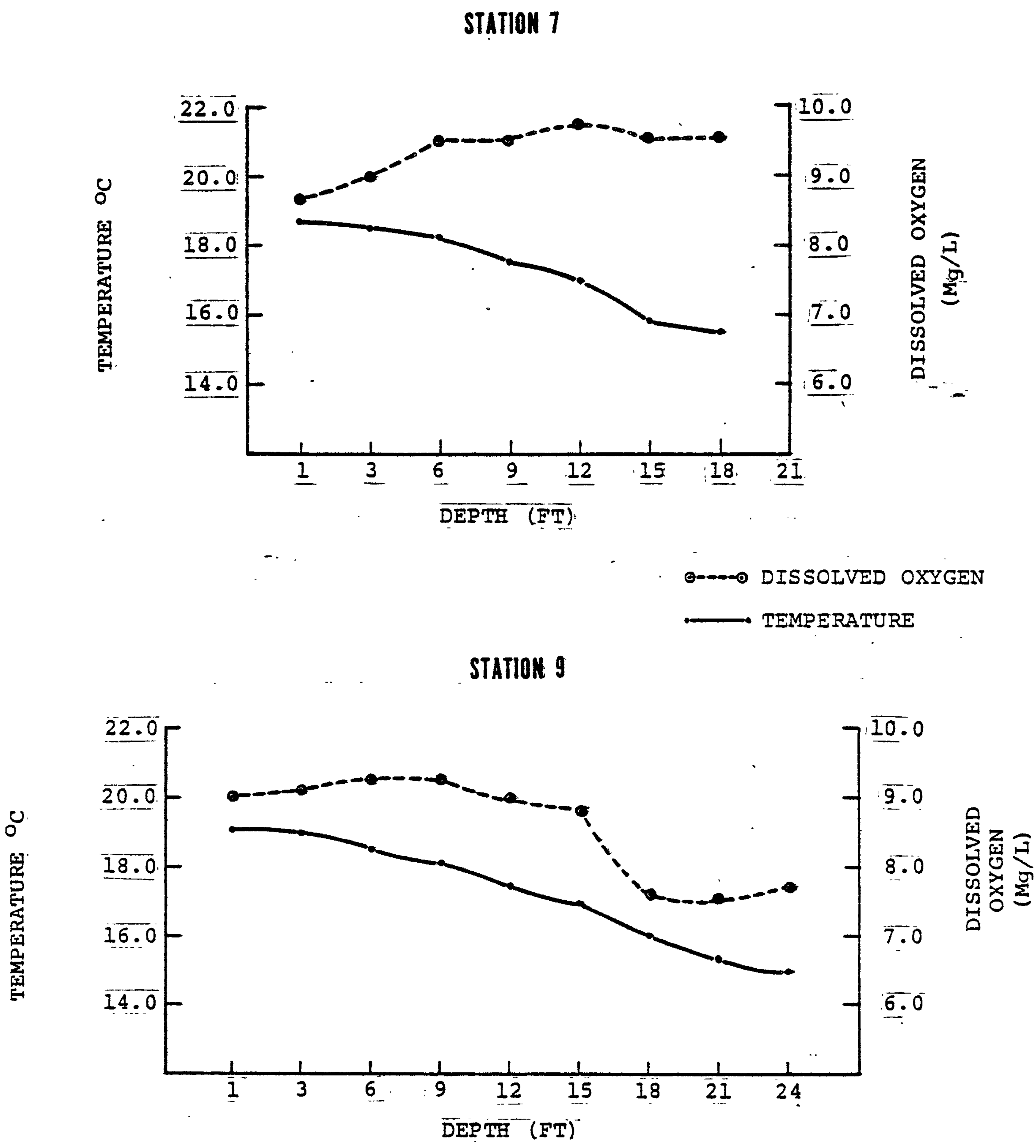


Figure 7

TEMPERATURE AND DISSOLVED OXYGEN PROFILE

June 4-5, 1974

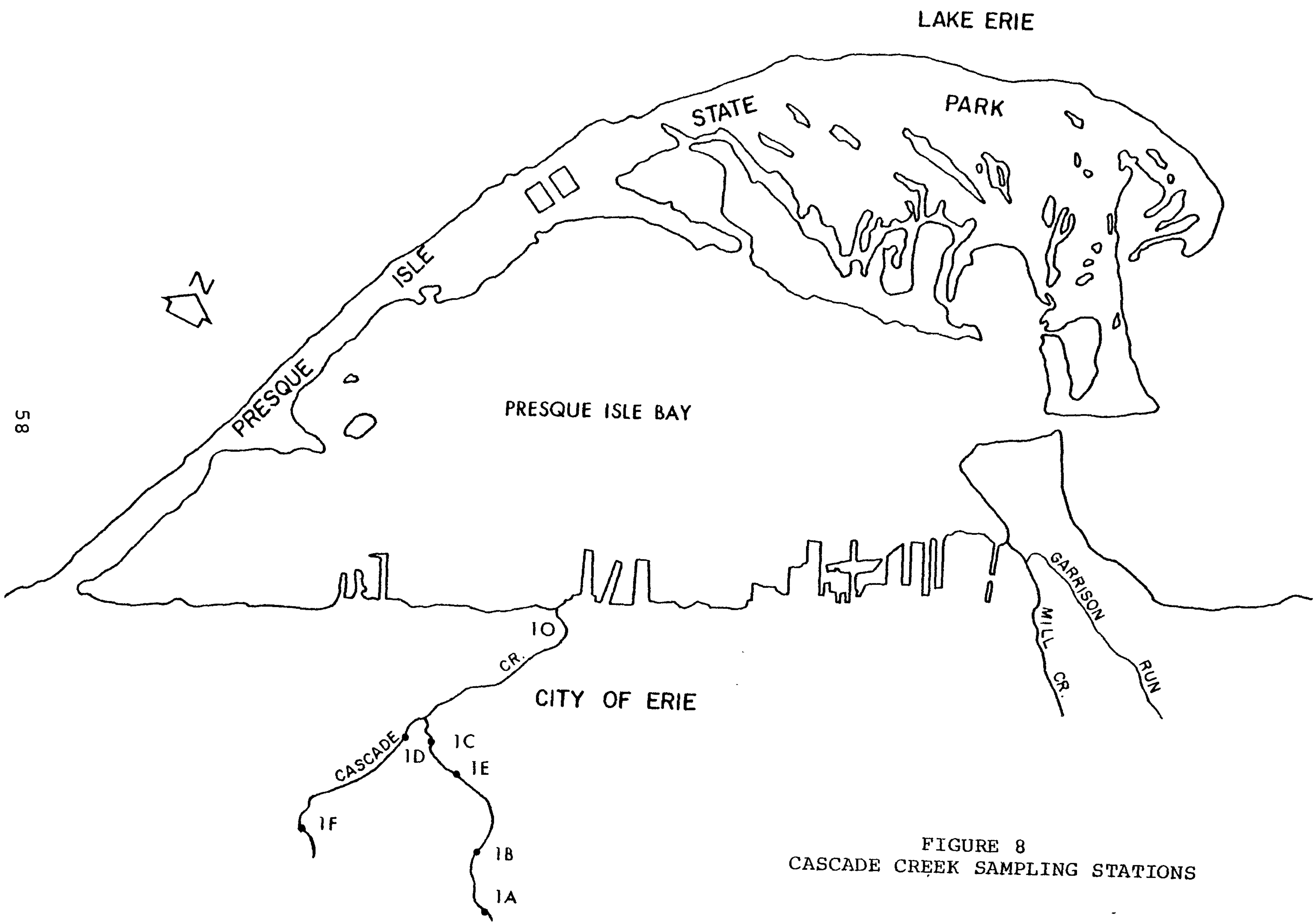


FIGURE 8
CASCADE CREEK SAMPLING STATIONS

sented in Table 7. In general, nutrient levels in Cascade Creek were higher than those in the bay and lake areas. Ammonia concentrations ranged from 0.10 to 5.88 mg/l and averaged 1.51 mg/l. Many of these values exceeded the water quality criterion of 0.5 mg/l for public water supplies. Kjeldahl nitrogen concentrations were also high, ranging from 0.11 to 5.80 mg/l and averaging 2.21 mg/l. Organic nitrogen, however, was lower than the bay and lake stations. Phosphorus levels were greater in Cascade Creek than in the bay with average total phosphorus and dissolved orthophosphate levels of 0.14 mg/l and 0.025 mg/l respectively.

Total solids and suspended solids were higher in Cascade Creek with average concentrations of 345 mg/l and 34 mg/l respectively. The higher total solids concentrations, besides reflecting higher suspended solids levels, indicates that total dissolved substances were greater in Cascade Creek than in the bay and lake areas. In Cascade Creek suspended solids ranged from 1 to 170 mg/l with the maximum concentration occurring in April.

The average BOD in Cascade Creek was slightly higher than average bay values. Color averaged 8.8 units and ranged from 4 to 16 units. The color in Cascade Creek was about the same as the average ambient bay and lake water.

Heavy metal concentrations were, in general, higher in Cascade Creek than in the bay and lake. In particular, concentrations of iron, lead, zinc and aluminum were high.

In Cascade Creek, iron ranged from 0.58 to 12.47 mg/l and averaged 2.86 mg/l. In the lake and bay areas, however, iron ranged from 0.10 to 0.82 mg/l. It is highly probable that the dissolved iron, although not measured, exceeded the Pennsylvania standard of 0.3 mg/l.

In Cascade Creek, lead ranged from 0.018 to 0.286 mg/l and averaged 0.077 mg/l while in the bay and lake areas it ranged from 0.002 to 0.022 mg/l. Water quality criteria for livestock public water supplies set a limit of 0.05 mg/l for lead. Thus, at times, water in Cascade Creek exceeds this limit.

Zinc ranged from 0.006 to 0.192 mg/l and averaged 0.055 mg/l in Cascade Creek while it ranged from 0 to 0.065 mg/l in the bay and lake areas. The zinc criterion for public water supplies is 5 mg/l, indicating that these waters do not exceed this limit.

Aluminum ranged from 0.2 to 3.8 mg/l in Cascade Creek and from 0.05 to 0.93 mg/l in the bay and lake areas. No limits

TABLE 7

SUMMARY DATA FOR STREAM STATIONS

CONSTITUENTS	Station 1 Mean	Station 1 Range
pH	7.6	7.2-7.9
Alkalinity mg/l	114	93-132
Color Units	8.8	4.0-16.0
Total Solids mg/l	345	262-400
Suspended Solids mg/l	34	1-170
Biological Oxygen Demand mg/l	9.8	6.0-19.0
Ammonia as N mg/l	1.51	0.10-5.88
Nitrite as N mg/l	0.13	0.01-0.36
Nitrate as N mg/l	1.51	0.10-5.88
Organic Nitrogen as N mg/l	0.05	0.01-0.18
Total Kjeldahl Nitrogen as N mg/l	2.21	0.11-5.80
Dissolved Orthophosphate as P mg/l	0.025	0.010-0.058
Total Dissolved Phosphorus as P mg/l	0.08	0.03-0.17
Total Phosphorus as P mg/l	0.14	0.03-0.30
Total Organic Carbon mg/l	-	-
Iron as Fe ug/l	2862	580-12,470
Copper as Cu ug/l	22.7	6.6-66.0
Lead as Pb ug/l	77.3	18.0-286.0
Zinc as Zn ug/l	55.0	6.0-192.0
Cadmium as Cd ug/l	2.55	0.0-4.40
Chromium as Cr ug/l	26.45	4.00-66.00
Aluminum as Al ug/l	1017	200-3820
Mercury as Hg ug/l	1.91	0.00-4.35

TABLE 7 (cont'd)

SUMMARY DATA FOR STREAM STATIONS

CONSTITUENTS	Station 3 Mean	Range
pH	7.0	6.7-7.3
Alkalinity mg/l	118	63-161
Color Units	14.2	4.0-35.0
Total Solids mg/l	361	223-447
Suspended Solids mg/l	34	4-68
Biological Oxygen Demand mg/l	68.2	9.0-120.0
Ammonia as N mg/l	2.74	0.14-8.40
Nitrite as N mg/l	0.30	0.03-1.14
Nitrate as N mg/l	2.74	0.14-8.40
Organic Nitrogen as N mg/l	0.79	0.29-1.50
Total Kjeldahl Nitrogen as N mg/l	4.02	0.43-9.90
Dissolved Orthophosphate as P mg/l	0.507	0.008-1.150
Total Dissolved Phosphorus as P mg/l	0.32	0.01-0.74
Total Phosphorus as P mg/l	1.12	0.11-2.30
Total Organic Carbon mg/l	-	-
Iron as Fe ug/l	2670	566-8400
Copper as Cu ug/l	77.5	10.0-159.0
Lead as Pb ug/l	40.3	17.0-82.0
Zinc as Zn ug/l	157.6	51.0-348.0
Cadmium as Cd ug/l	3.91	0.12-10.0
Chromium as Cr ug/l	39.23	0.00-88.0
Aluminum as Al ug/l	612	180-1800
Mercury as Hg ug/l	1.64	0.10-4.10

have been established for aluminum in these waters. However, the aluminum level is higher in Cascade Creek than in the lake.

In addition to the sampling of Cascade Creek just upstream of its confluence with the bay (Station 1), Cascade Creek was sampled at six other locations in an attempt to determine the sources of stream pollution. The following stations were sampled:

Station	Location
1A	W. 25th Street & Bauer Ave.
1B	W. 18th Street & Industrial Dr.
1C	W. 8th Street & Greengarden St.
1D	W. 8th Street & Greengarden St.
1E	W. 12th Street & Weschler Rd.
1F	W. 12th Street (South of Villa Marie College)

Stations 1A, 1B, 1E and 1C were located on the east branch of Cascade Creek, while Station 1F and 1D were located on the west branch (see Figure 8).

Stations 1A through 1F were sampled at least twice, in May and June. Stations 1A through 1D were initially sampled in December before Stations 1E and 1F were added. In December, the suspended solids, nutrients, BOD, color and heavy metals measured in Cascade Creek were relatively low. In June these constituents were slightly higher, but were not significant. However, in May, these constituents were very high. For example, in December and June the suspended solids concentration was 6 mg/l at Station 1A while in May the suspended solids concentration was 162 mg/l. Examination of rainfall data indicated that significant amounts of rain fell during the month of May. These May samples were collected on May 9th under the conditions below:

Date	Rain (inches)
5/2/74	0.20
5/3/74	0.26
5/5/74	0.33
5/8/74	0.31
5/9/74	0.19

Thus, even a light rainfall for an extended period as noted above can produce significant changes in the stream water quality. This rain-related change in water quality indicates that much of the pollution load in Cascade Creek is caused by storm drains.

Evaluation of the data for Stations 1A through 1F indicates that solids, nutrients and organic material enter the east branch of Cascade Creek all along its length and not at any one location.

The west branch, however, appears to pick up most of these constituents between Station 1F and 1D. Most heavy metals also appear to follow this pattern with the exception of iron which appears to increase significantly between the confluence of the east and west branch and Station 1.

Mill Creek

Mill Creek travels throughout the area from the very southern part of the city, where it is an open, rather clean stream, to the bay. From the central section of the City of Erie to the bay, Mill Creek is enclosed in a tube and receives many stormwater discharges, sewer system overflows and illegal sewer discharges. Just below the sewage treatment plant, Garrison Run, a stream to the east of Mill Creek, joins Mill Creek. Garrison Run is also enclosed throughout the city and receives stormwater discharges, sewer overflows and drainage from Penn Central. A detailed evaluation of Garrison Run and Penn Central is provided in Sections VIII and IX respectively.

Mill Creek at Station 3, located just downstream of the sewage treatment plant, but upstream of its confluence with Garrison Run, is heavily polluted with both organic material and heavy metals, as shown in Table 7. Suspended solids ranged from 4 to 68 mg/l and averaged 34 mg/l. Nutrient concentrations were high with average concentrations of ammonia, Kjeldahl nitrogen, organic nitrogen and total phosphorus of 2.74, 4.02, 0.79 and 1.12 mg/l respectively. Ammonia levels exceeded the criteria of 0.5 mg/l for public water supplies. Dissolved orthophosphate levels ranged from 0.008 to 1.150 mg/l and averaged 0.507 mg/l.

Biochemical oxygen demand (BOD) was also very high, ranging from 9 to 120 mg/l with an average of 68.2 mg/l. Color ranged from 4 to 35 units and averaged 14.2 units. Heavy metal concentrations were also high, especially for iron and zinc.

Garrison Run

Garrison Run is a natural stream that flows through most of Erie City in a tube. Like Mill Creek, this tube receives stormwater runoff, sewer overflows and other miscellaneous industrial and sanitary discharges. Garrison Run is located east of Mill Creek, along East Avenue and Wayne Street. It combines with Mill Creek below the sewage treatment plant. Samples were collected from Garrison Run upstream of its confluence with Mill Creek (Station 3A) three times during the study.

One of the three samples contained high levels of suspended solids (232 mg/l), iron (14.11 mg/l) and aluminum (7.04 mg/l). In general, the water quality in Garrison Run is degraded and is indicative of industrial and sanitary pollution. A detailed analysis of Garrison Run is presented in Section VIII.

Sediment Analysis

Sediment samples were collected at Stations 2, 4, 5, 7, 8 and 9 in June. Both nutrients and heavy metal concentrations were highest at Station 5, except for nitrate and lowest at Station 8, except for phosphate. Lake Stations 7 and 9 had similar heavy metal concentrations. The nutrient concentrations at the two stations were somewhat different. The nitrate concentration was 250 mg/l at Station 9 and 50 mg/l at Station 7. Ammonia concentrations showed an opposite pattern with a value of 120 mg/l at Station 7 and 10 mg/l at Station 9. Both total and orthophosphate levels were three times higher at Station 7 than at Station 9. Both nutrient and heavy metal concentrations were higher at Station 2 than at Station 4. Station 4 had lower concentrations of aluminum, chromate, zinc, copper, and iron than Stations 7 and 9; but Station 2 had higher concentrations of these constituents.

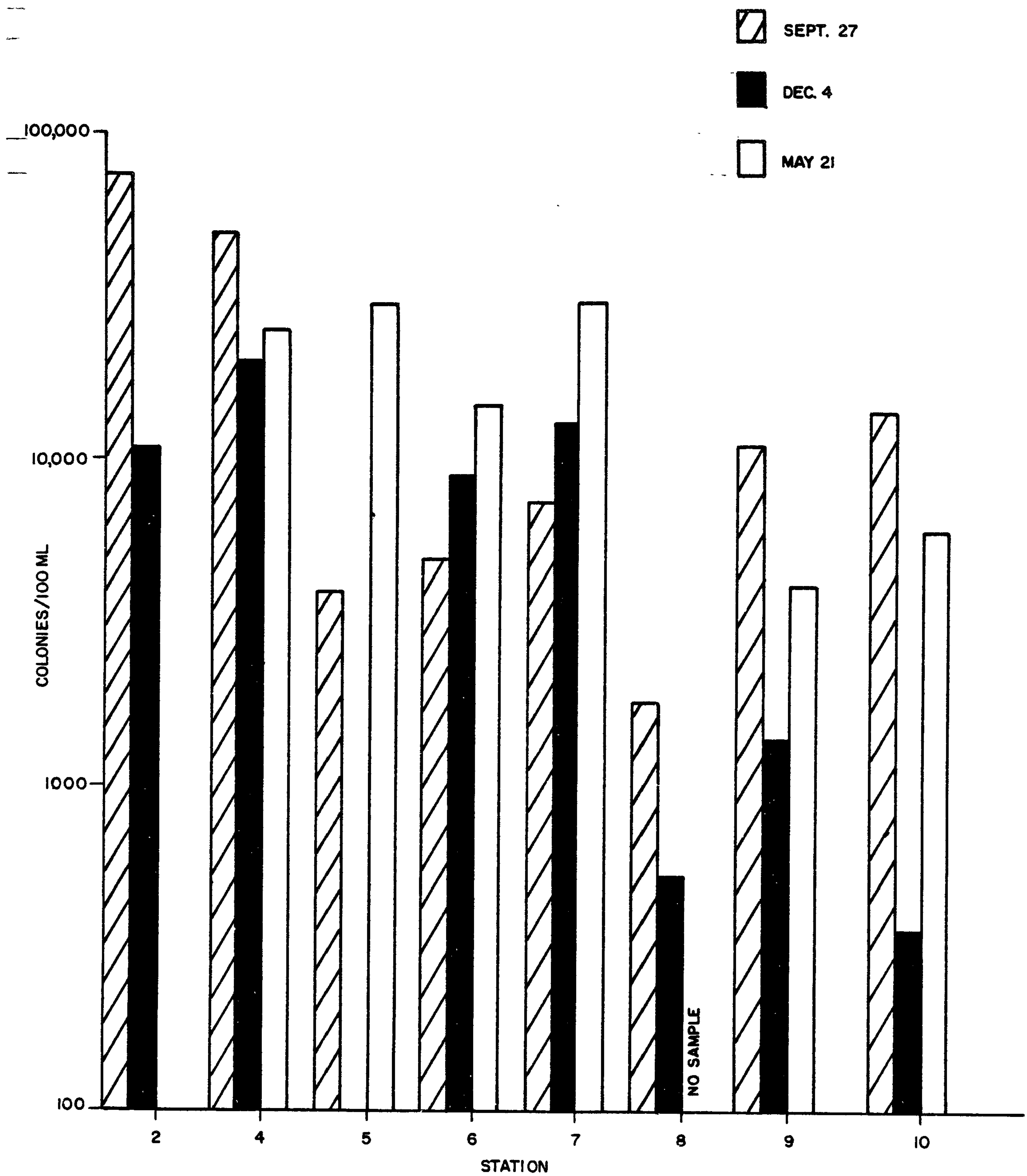
Bacteria

The maximum total bacteria concentration in the lake and bay was 1,200,000 colonies per ml at Station 6 on June 4. The lowest concentration (less than 10 colonies per ml) was at Station 5 on December 4. No seasonal pattern was evident. Stations 2 and 4 had the highest overall concentrations and Station 8 had the lowest concentration although there were fluctuations in values at all stations. Total and fecal coliform bacteria concentrations did not follow the same pattern as total bacteria concentrations. High concentrations of fecal and total coliform bacteria occurred at Station 2 in September, but in general, the highest concentrations for the area, particularly the lake area, occurred in December (Figure 9).

All bacteria concentrations in the tributaries (Stations 1 and 3) were higher than in the lake and bay, and Station 3 concentrations were higher than those at Station 1 except for the May samples. Fecal coliform concentrations were high at Station 3, and total coliform concentrations were generally higher than at Station 1 (Figure 10). The highest fecal coliform concentrations occurred at Station 3 in October. This value exceeded 1,000,000 colonies per 100 ml. Garrison Run contained high levels of coliform and fecal coliform bacteria on all three sampling surveys. Total coliforms ranged from 23,400 to 61,000 per 100 ml and fecal coliforms ranged from 160 to 7,200 per 100 ml. The total coliform bacteria levels in Garrison Run exceeded state water quality criteria.

FIGURE 9

TOTAL BACTERIA FOR LAKE STATIONS



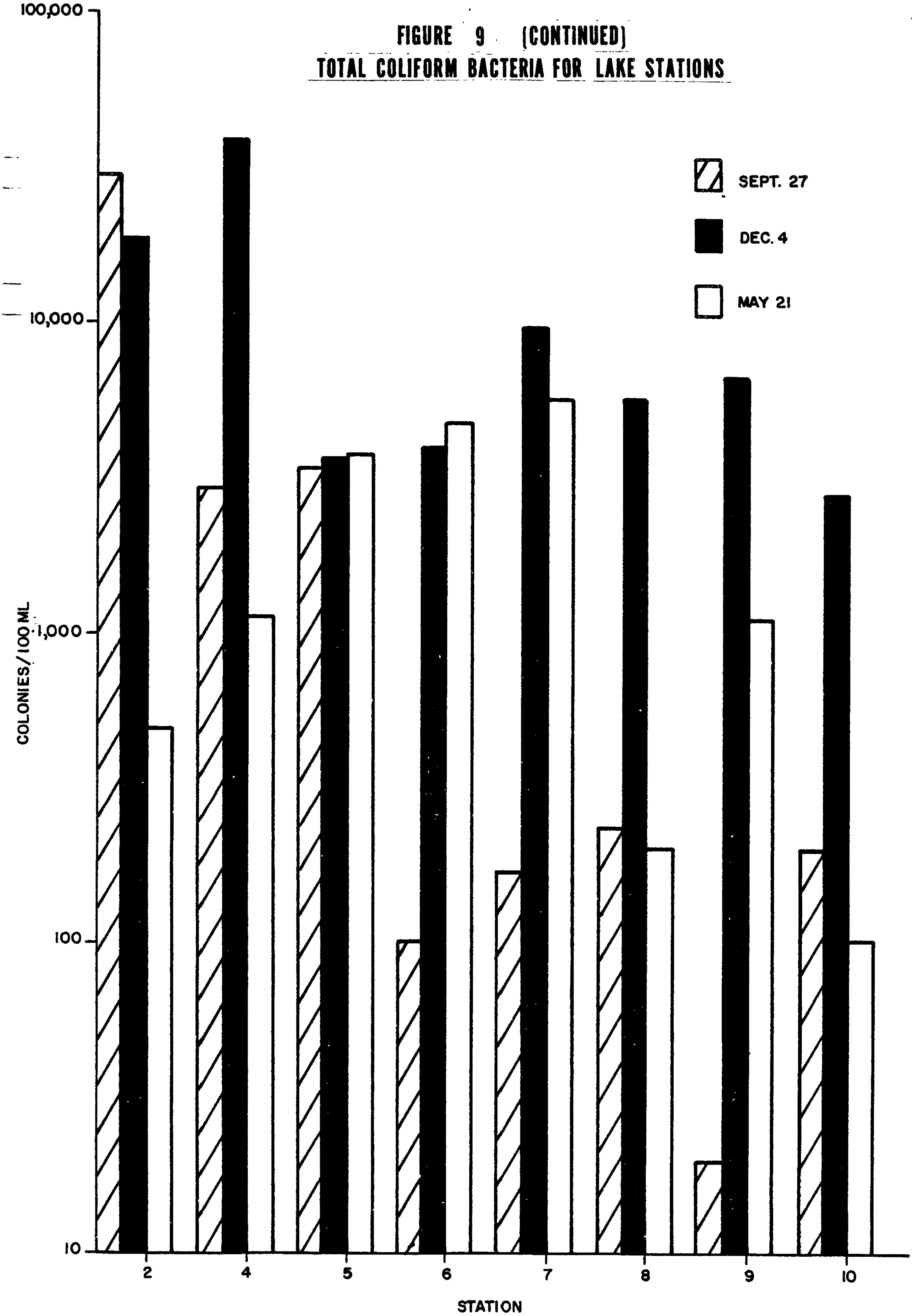


FIGURE 9 (CONTINUED)
TOTAL COLIFORM BACTERIA FOR LAKE STATIONS
SEPT. 27
DEC. 4
MAY 21
100,000
10,000
1,000
100
10
COLONIES/100 ML
2
4
5
6
7
8
9
10
STATION

FIGURE 9 (CONTINUED)
FECAL COLIFORM BACTERIA FOR LAKE STATIONS

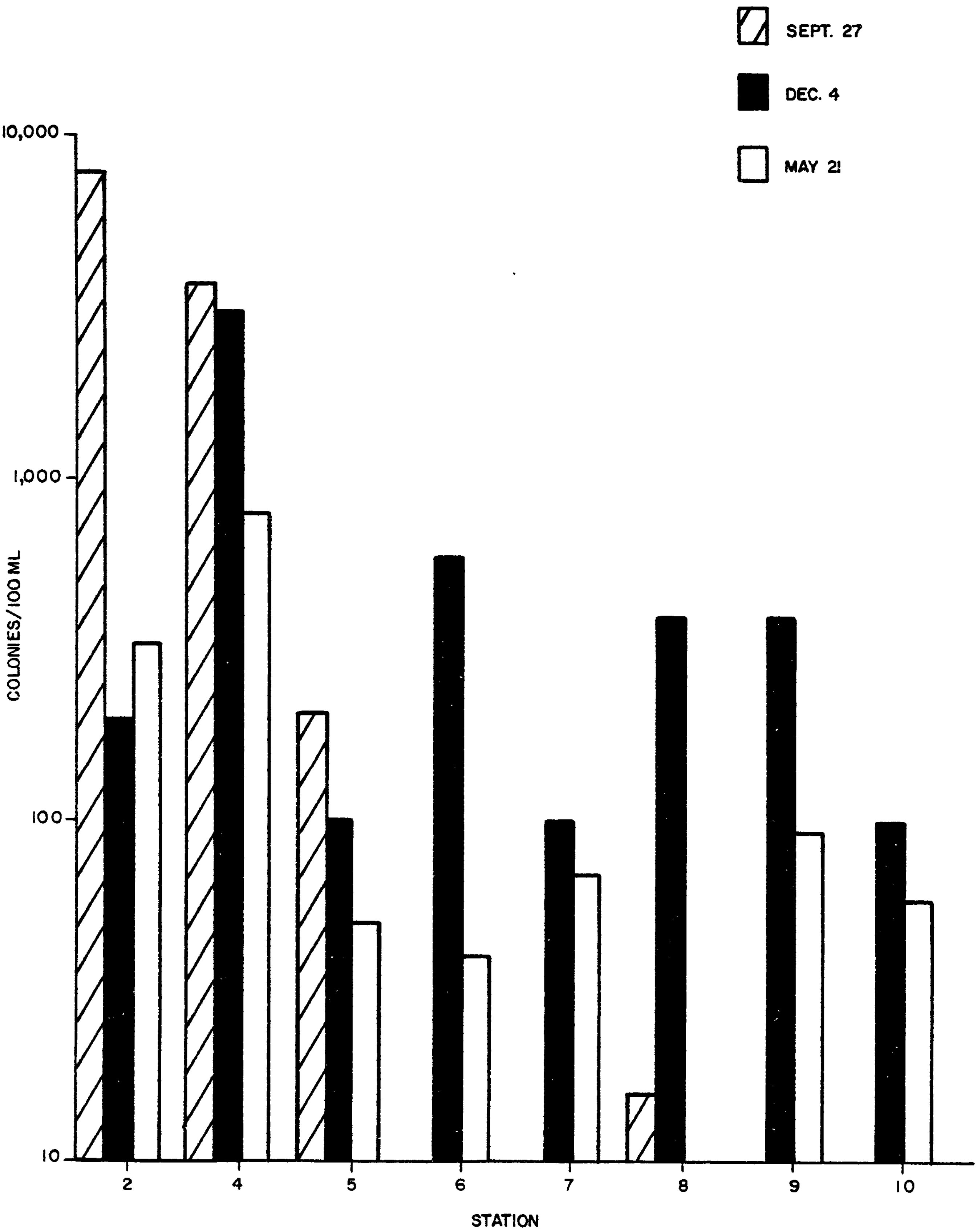


FIGURE 10
TOTAL BACTERIA FOR STATIONS 1 AND 3

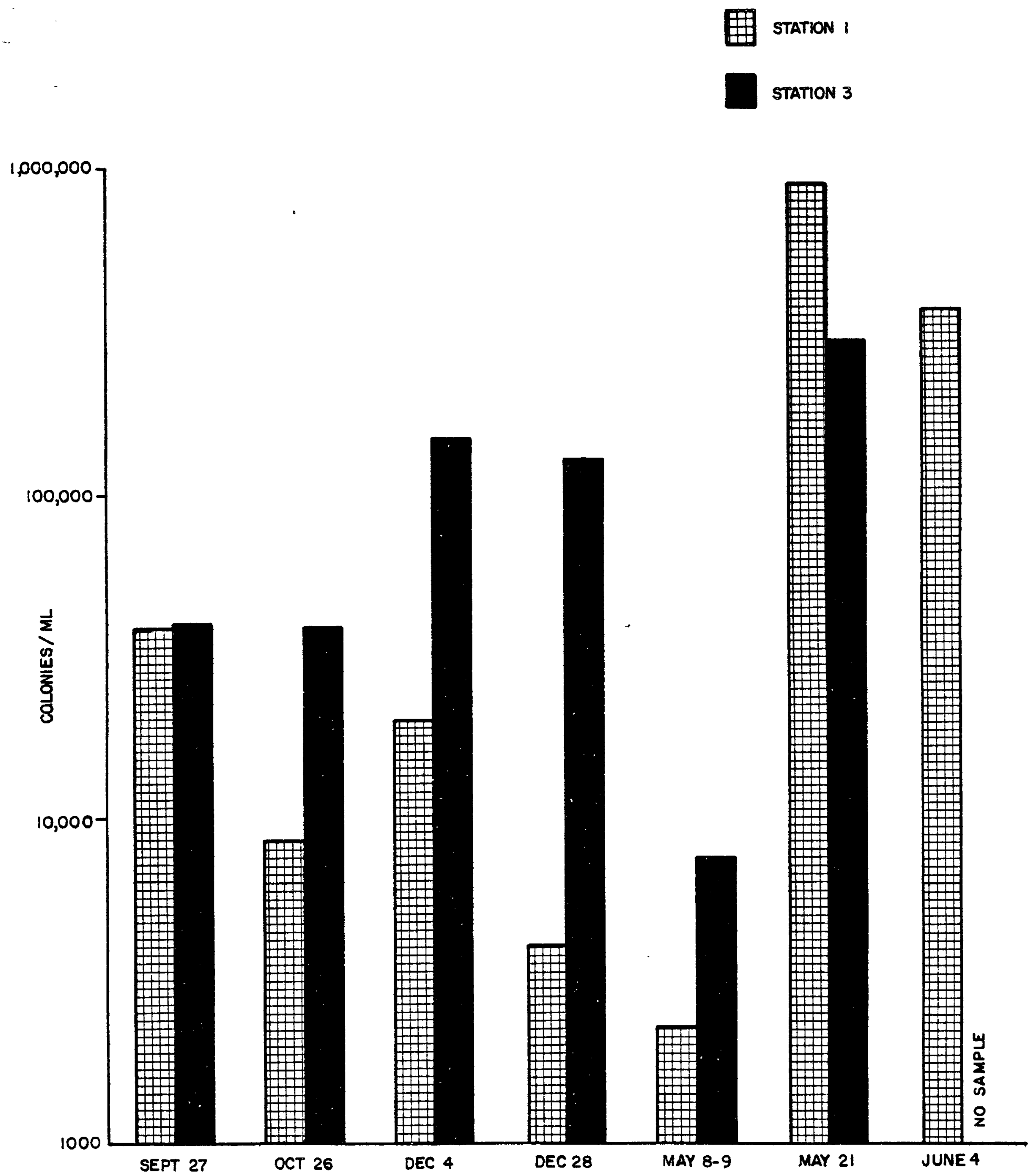
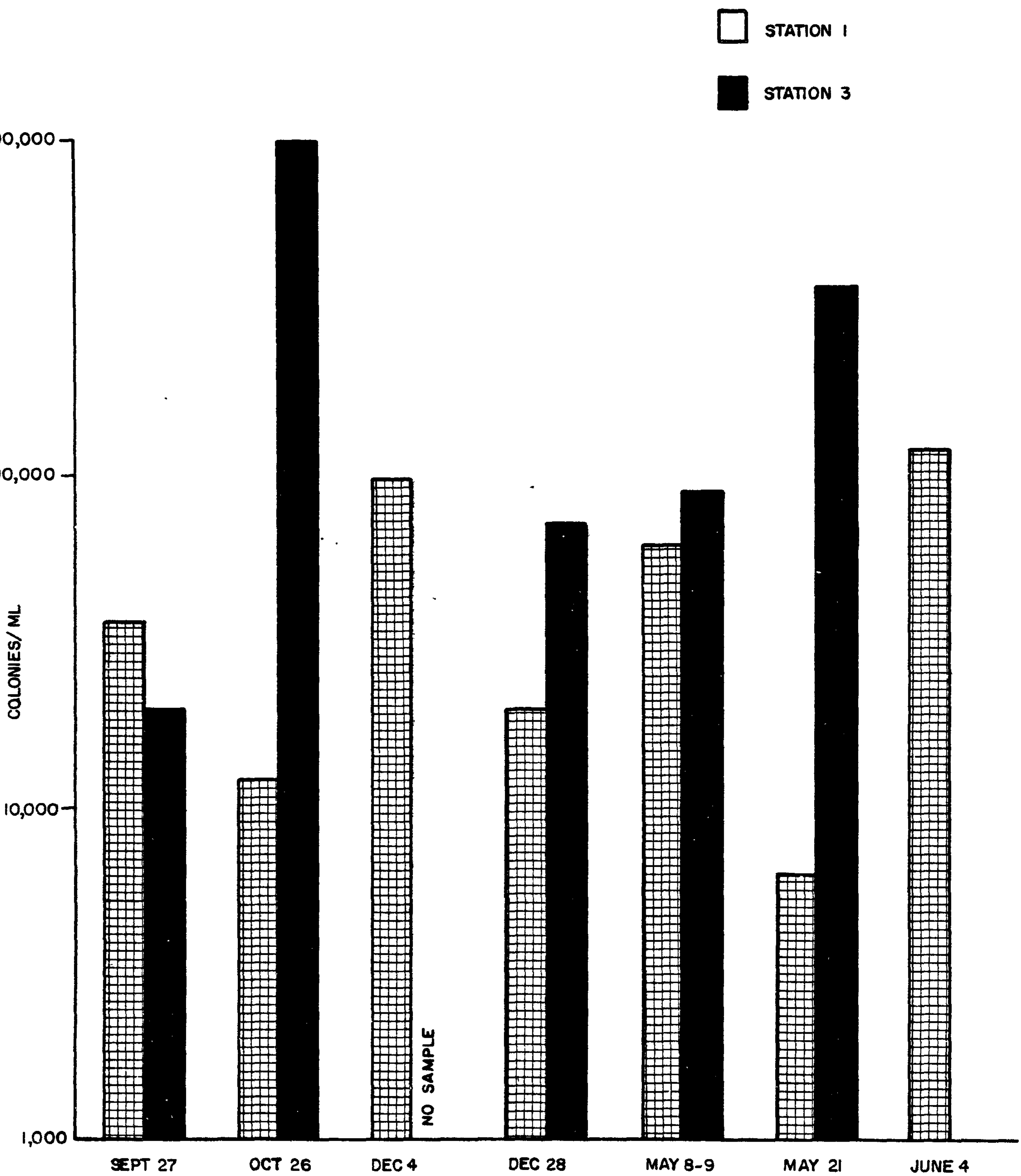


FIGURE 10 (CONTINUED)

TOTAL COLIFORM BACTERIA FOR STATIONS 1 AND 3



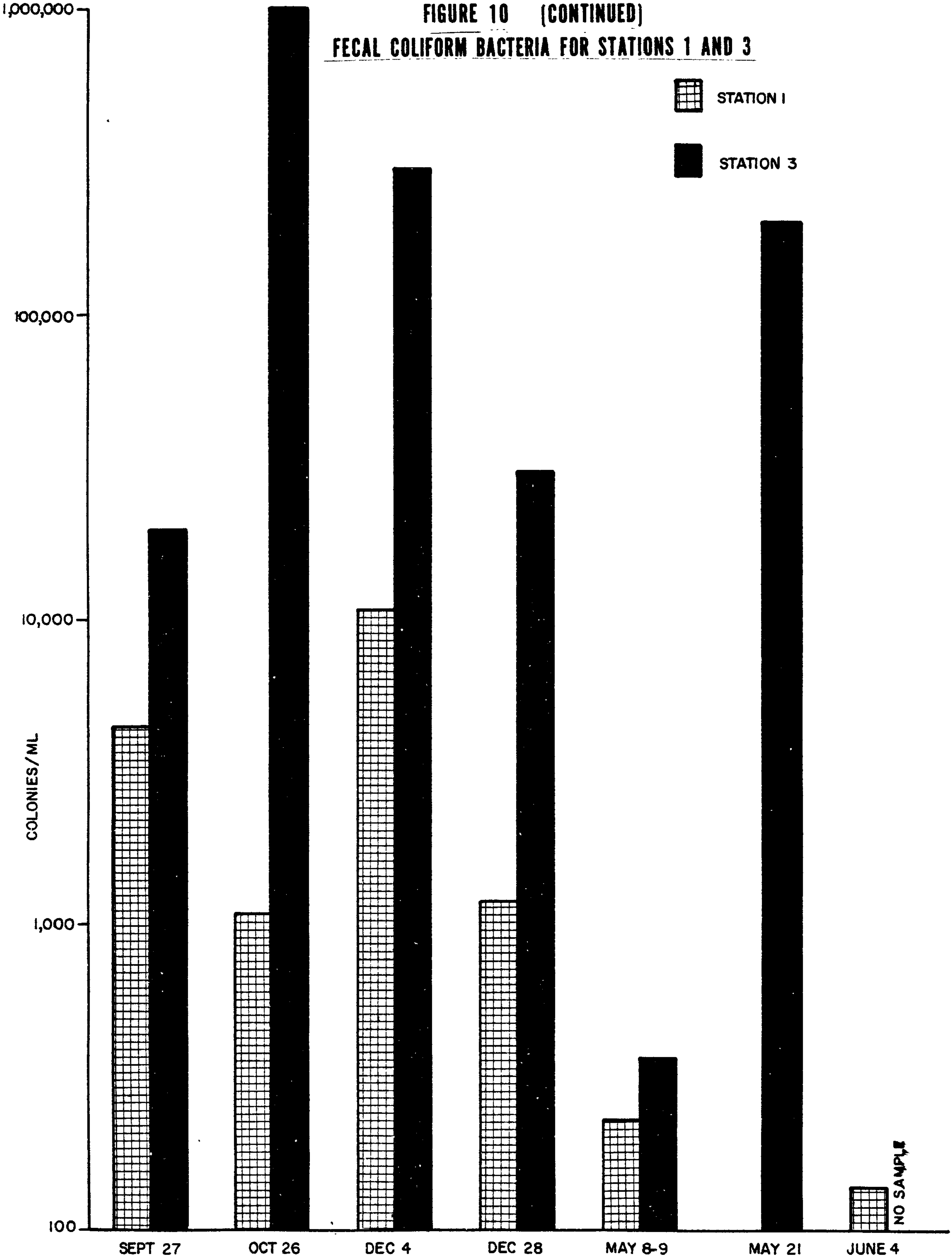


FIGURE 10 (CONTINUED)
FECAL COLIFORM BACTERIA FOR STATIONS 1 AND 3
STATION 1
STATION 3
1,000,000
100,000
10,000
1,000
100
COLONIES/ML
NO SAMPLE
SEPT 27
OCT 26
DEC 4
DEC 28
MAY 8-9
MAY 21
JUNE 4

Bacteria concentrations are often correlated with rainfall because of the high bacteria content of soil that results in bacteria entering waterways with ground runoff. The high fecal and total coliform concentrations found in the study are probably not a result of runoff conditions. Concentrations did not increase and decrease at the same time at different stations and total bacteria concentrations did not exhibit the same pattern as coliform bacteria as would be expected with runoff. Fecal coliform concentrations were particularly high near the sewage treatment plant (Station 3).

The higher coliform concentrations at the lake stations in the winter may be a result of greater bacteria longevity in cold water. Coliform bacteria are usually short-lived in water; however, they may become dormat at low temperatures. These dormant cells could then grow when incubated in the laboratory. These potentially viable cells could be carried by currents to areas away from their source. The fact that winter bacteria concentrations increased in the lake but not in the tributaries suggests Stations 1 and 3 were close to the source of contamination, and therefore, cell viability was not affected by temperature. Fecal and total coliform bacteria concentrations at Stations 2 and 4 were higher than at other stations at some sampling times, but not at all times as might be expected because of their proximity to the tributaries. The high total coliform concentrations at Stations 6, 7 and 9 in May could be indicative of rainfall and runoff since total bacteria concentrations were also high.

The bacterial findings of this study are in agreement with previous studies performed in the area. Zagorski and Galus (1972) reported Mill Creek water contributed to the bacterial pollution of Presque Isle Bay. <u>Salmonella</u> species were isolated in the tributary and near the shore, but not in the middle of the bay.

Difference in bacteria concentrations between the lake and bay occurred particularly for coliform bacteria. However, there were significant variations in these values. In September, and October, fecal and total coliform bacteria concentrations were higher in the bay than in the lake. Bacteria concentrations were frequently higher at Stations 2 and 4 than at the other stations, but there were many exceptions.

<u>Plankton</u>

Plankton measurements were collected with a No. 20 mesh plankton net. Colonial forms were counted as individual colonies. The plankton analyses were meant to present a broad overview for comparative purposes. They are relative values and should not be considered as indicative of total plankton. Lake Erie plankton exhibited seasonal changes in numbers and taxonomy as well as differences between stations. In September, there were higher numbers of blue-green algae in the bay than in the lake and more diatoms in the lake than in the bay (Figure 11). The number of green algae was slightly higher in the bay and zooplankton were found only in the bay. Pediastrum was the most abundant genus of green algae throughout the area in September. The most common diatom genera were Fragilaria and Tabellaria. Tabellaria was more abundant at stations in the lake than in the bay. Blue-green algae were present at all stations but Station 10. The most abundant genera were Oscillatoria and Anabaena, and these genera occurred in the greatest number at Station 5. In September the maximum number was 8,000 organisms per liter at Station 4. The high algal population at Station 5 is additional evidence of the highly productive nature of Misery Bay. Aquatic Ecology Associates (1973) reported that Misery Bay was a highly productive area and contained the largest and most diverse fish population. The low algal population at Station 4 is further evidence of the poor water quality conditions caused by Mill Creek.

In October plankton numbers declined at all stations, but the genera of green algae and diatoms present did not change significantly. Aphanazomenon was present at all the lake stations and was the most abundant blue-green algae at Stations 2 and 5. The maximum number was 8,640 organisms per liter at Station 2, and the minumum was 1,900 organisms per liter at Station 6. By December, plankton numbers had decreased to less than 5,000 organisms per liter in the lake and bay. Differences in genera between the lake and the bay remained (Figure 11). Blue-green algae decreased to below 200 organisms per liter and a change in dominance occurred in the lake and bay. Diatoms were more numerous in the bay than in the lake and green algae were more numerous in the lake. The decrease in plankton numbers continued through December.

Plankton populations began increasing in May. In the lake and bay, the concentrations ranged from 2,607 organisms per liter at Station 4, to 8,956 organisms per liter at Station 8. In general, diatoms were the dominant algae type in the bay and green algae were the dominant algae in the lake. Zooplankton numbers were low in both areas and no blue-green algae were observed. Numbers had not increased significantly in June and there were no blue-green algae present.

The plankton at the stream stations (1 and 3) did not follow the same pattern as the lake and bay plankton. With the exception of station 3 on October 25, diatoms and zooplanktons were the dominant organisms. The greatest number of plankton (32,000 org/l) at Station 1 occurred in October, and

FIGURE 11
LAKE ERIE PLANKTON SEPTEMBER 27,1973

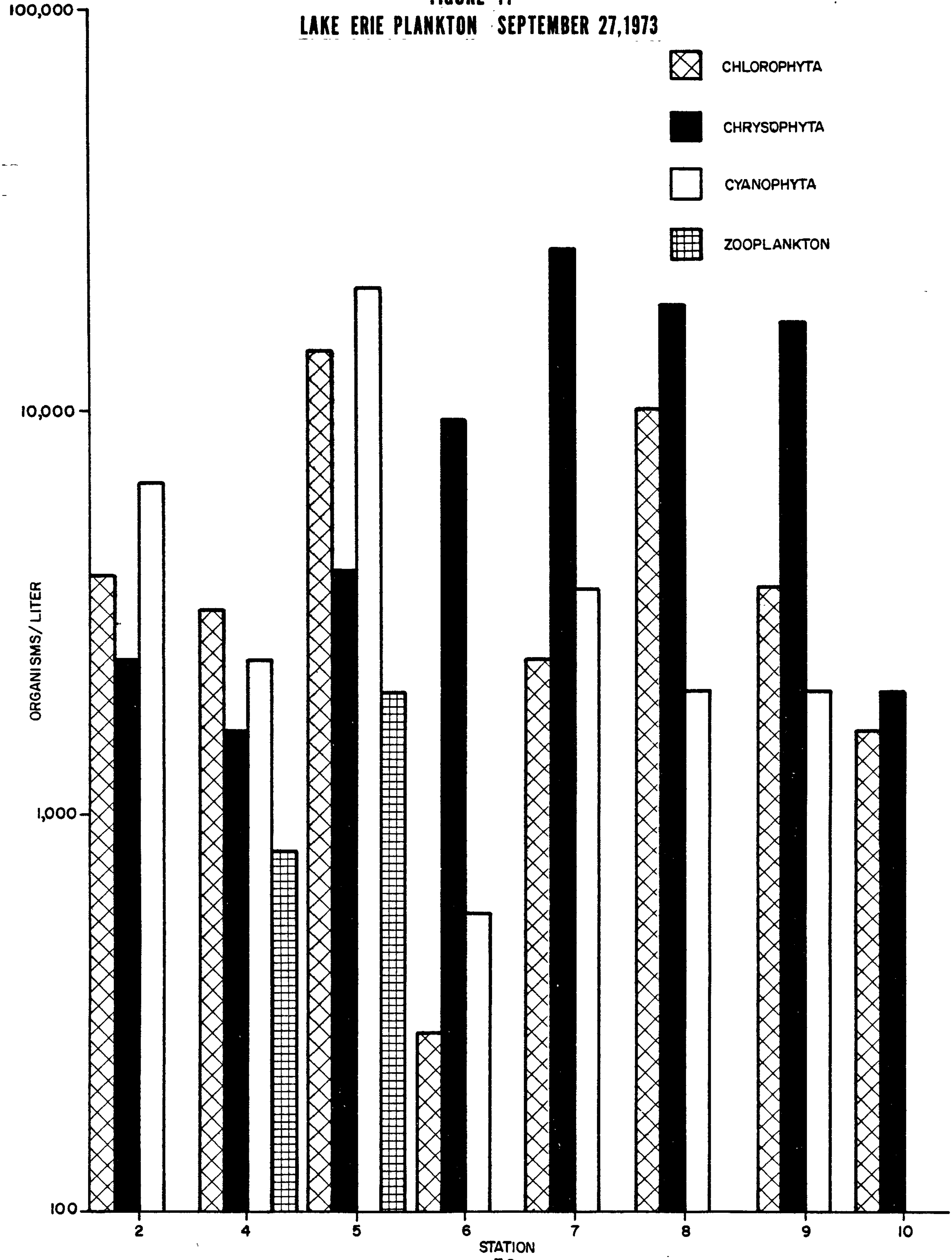


FIGURE 11 (CONTINUED)
LAKE ERIE PLANKTON MAY 29, 1974

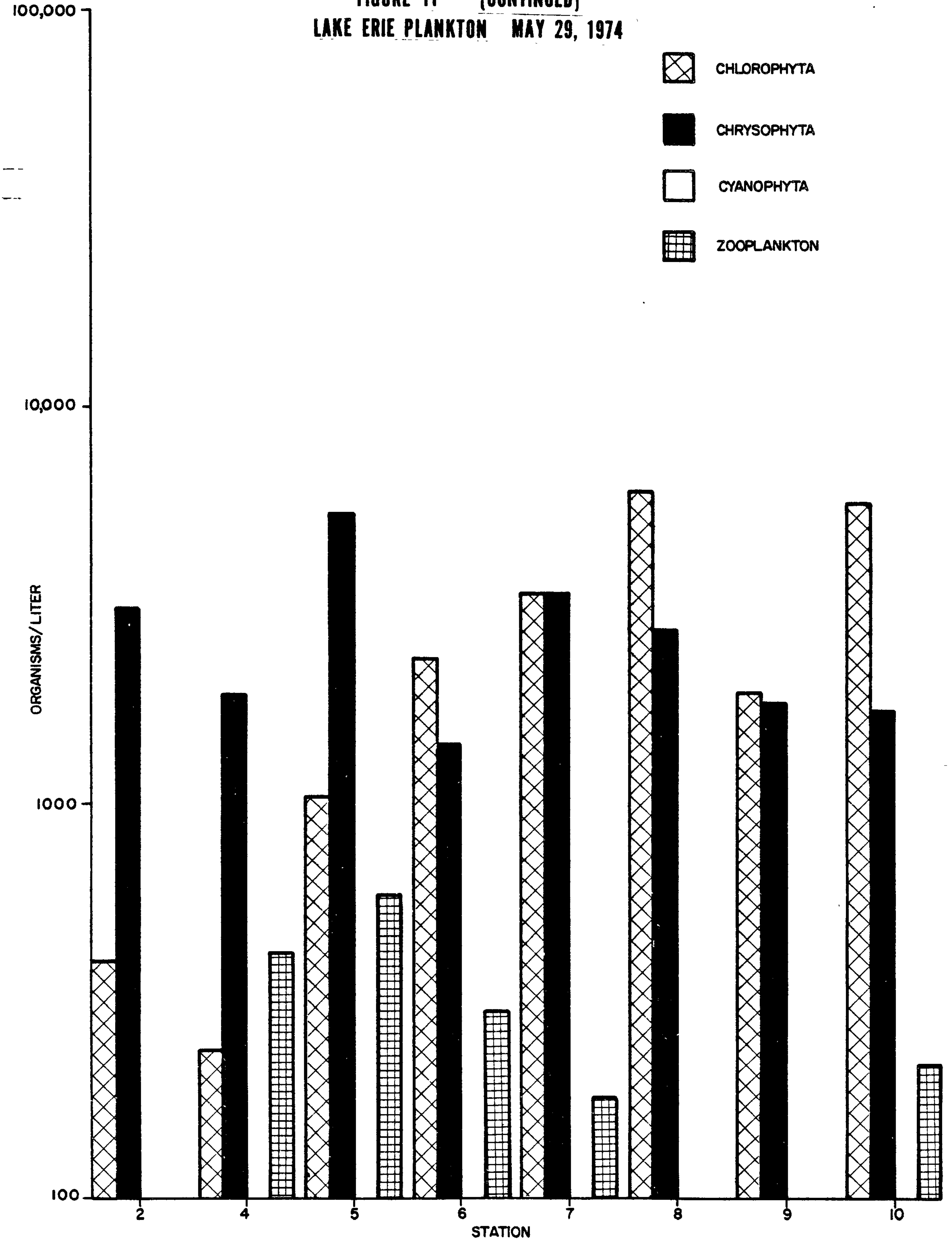
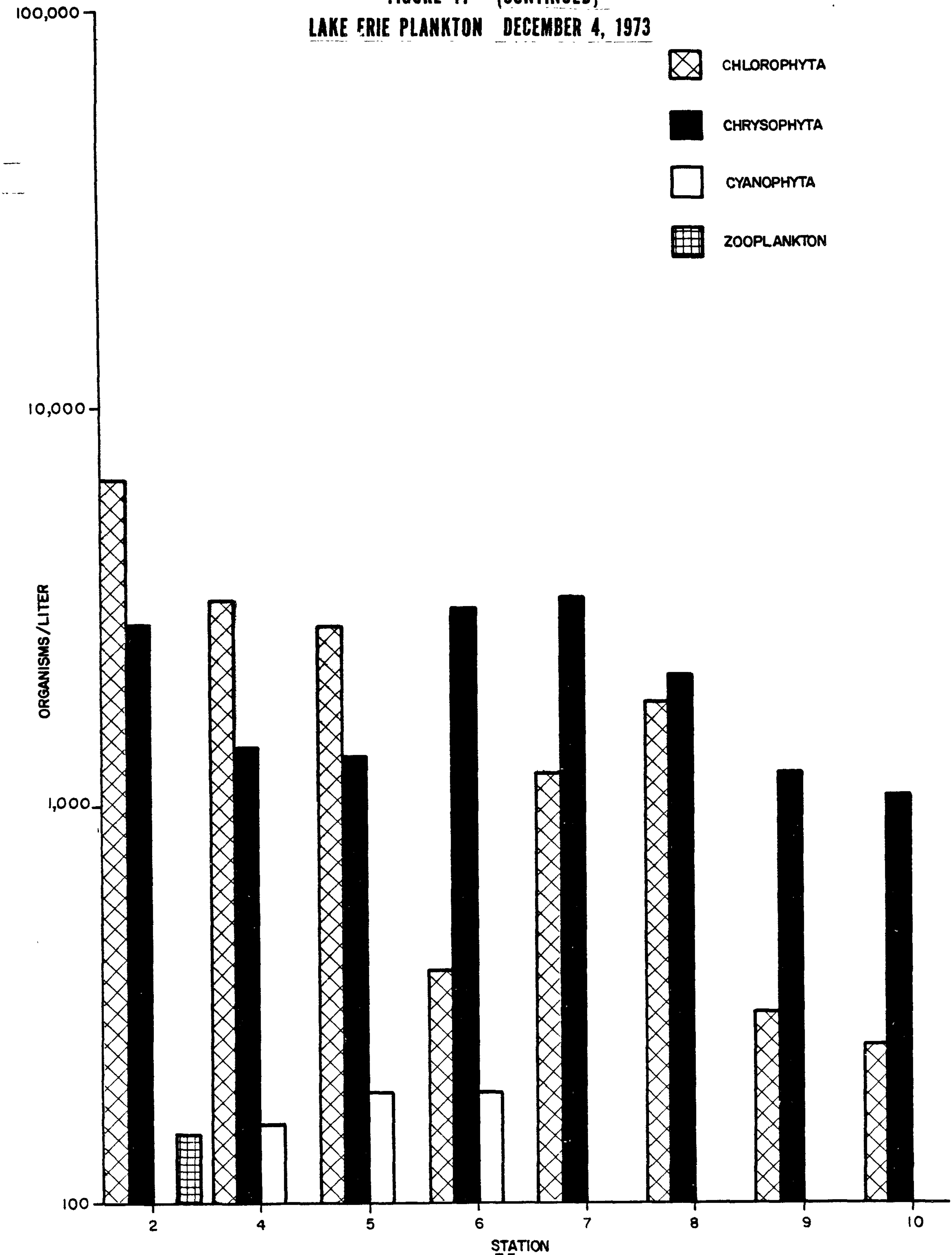


FIGURE 11 (CONTINUED)
LAKE ERIE PLANKTON DECEMBER 4, 1973



the greatest number (119,854 org/l) at Station 3 occurred in May. Although plankton numbers decreased in December, they were also low in September and did not follow a definite seasonal pattern. Because of the relatively small size of both Cascade and Mill Creeks, the plankton measured should be considered to be a pseudoplankton, in that a real indigenous plankton community would not exist in streams such as these. Therefore, the plankton results for both streams are an indication of the algae attached to rocks and other materials in the stream, including the stream bottom. Water current tears many of the attached algae loose to become pseudoplankton. These plankton analyses, however, are excellent indicators of the algal population and diversity of the streams.

Discussion

General

No distinct differences between the water quality of the bay and lake were apparent. There were differences in some parameters, such as bacteria and plankton, but in general there was greater fluctuation in values at one station for different sampling times than between stations for any one sampling time. This finding is surprising since water of rather poor quality enters the bay from Cascade Creek (Station 1) and Mill Creek (Station 3). There was no consistent correlation between values at Stations 1 and 2, or Stations 3 and 4 in spite of their proximity. There are several possible explanations for this situation: 1) substances entering from tributaries rapidly disperse as they enter the bay, 2) entering substances are picked up by currents and carried along a definite pathway and 3) materials settle out before they reach the main part of the bay.

Results of analyses of samples collected at Stations 4A, 4B and 4D indicate that the Mill Creek water may flow along a definite near-shore pathway northward towards Station 5 on the central section of the bay. This possible circulation pattern, presented in Figure 12, would also explain the high productivity observed at Station 5. Even if the Mill Creek water initially was blown towards the central section of the bay by easterly winds, it is possible that westerly winds would transport some of the organics and nutrients into Misery Bay (Station 5). However, the high productivity in Misery Bay is also attributable to the transport and sedimentation of organic material from the backwaters of Presque Isle State Park. Phytoplankton growth, death and decay in the protected waters of Misery Bay also contribute to the productivity of this area.

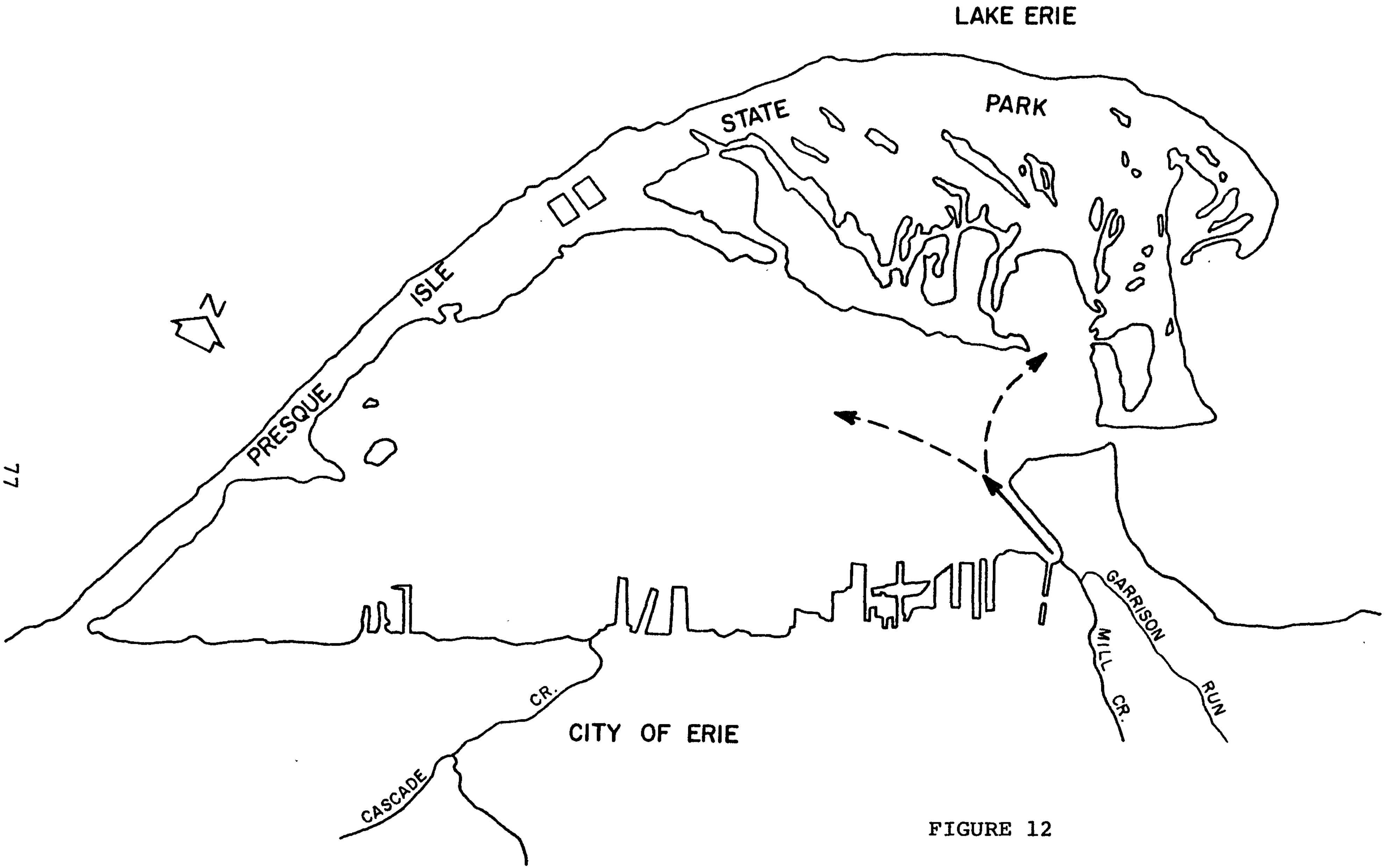


FIGURE 12

POSSIBLE BAY CIRCULATION PATTERN

The sediment data provided the greatest insight into the situation in the lake and bay. If substances rapidly settle out, the sediments from stations closest to the tributaries would have the highest concentrations of heavy metals and nutrients. The data show that Station 5 (Misery Bay) had the highest concentrations of heavy metals and nutrients in the sediments although the water at this station was not higher in these constituents than that of other stations. A possible explanation for this is that materials do not disperse or settle out rapidly, but are carried by currents to other areas. If these substances are carried in subsurface currents, it would explain why high nutrient and metal concentrations were not found in the surface samples collected at Station 5. The sediment data from Station 2 and 4 support the hypothesis that substances entering the lake do not disperse evenly, but are carried by currents. Substrate concentrations of nutrients and heavy metals were lower at Station 4 than at Station 2, although concentrations of substances in Mill Creek, which entered the lake near Station 4, were higher than concentrations in Cascade Creek, which entered near Station 2. If substances entering from tributary streams disperse evenly, then the nutrient and chemical concentrations would be higher at Station 4 than at Station 2.

Another explanation for the somewhat lower concentrations of metals near the mouths of streams could be that these metals are diluted by the settling of inert and other materials which enter the bay from these streams in large quantities (R.M. Boardman, Personal Communication).

Sediment concentrations for all parameters except phosphate and nitrogen were similar for Stations 7 and 9. These two stations were located in the main body of the lake and were approximately the same distance from shore. Station 9 sediments were high in nitrate, and Station 7 sediments were high in fixed ammonia, total phosphate and orthophosphate. This finding would indicate a possible oxygen depletion at Station 7 that retards oxidation of nitrogenous compounds, but the data do not support this theory. Temperature and dissolved oxygen profiles indicate high dissolved oxygen concentrations at the bottom for both stations. However, according to Dr. A.M. Beeton (Personel Communication), the absence of a low dissolved oxygen level at Station 7 does not preclude possible low DO at this station since it has been demonstrated that internal seiches move large masses of low DO water around in Lake Erie. Another possibility, however, is that the nitrogenous substances that settle out at Station 9 are already oxidized.

There were seasonal differences between the bay and the lake plankton. In May, diatom numbers were higher in the bay than in the lake, and green algae were more abundant in the lake than in the bay. In September the conditions were reversed; green algae were more abundant in the bay and diatoms were more abundant in the lake. Another difference occurred in the fall. Plankton numbers in the lake declined more rapidly than in the bay as shown by the September and October data. These differences may occur because the bay is more protected and less turbulent than the lake, and the temperature in the bay may not decrease as rapidly as in the lake. These conditions could result in greater plankton longevity in the bay than in the lake.

There was a definite difference between the water quality of the tributary streams and the lake. The water at Station 3 was of poor quality. The extremely high bacteria counts, particularly fecal coliforms, a mean biological oxygen demand of 68.2 mg/l, and an ammonia concentration of 8.40 mg/l indicate organic pollution. Although the quality of the water entering from Cascade Creek is of better quality than that from Mill Creek, it is still less than optimal and is indicative of organic and industrial pollution. In addition to high levels of organic matter, both streams have high concentrations of nitrates and phosphates that may or may not have an organic origin. Although in the breakdown of organic matter nitrates and phosphates are released, their presence can also be indicative of materials such as detergents and fertilizers.

The current flow patterns in Lake Erie and Presque Isle Bay may be an important consideration in evaluating the condition of the lake and the source of magnitude of substances entering the lake. The water entering from the two tributary streams studied is of poor quality. However, the findings of this study indicate that the impact of this water on the lake may not be confined to areas in the immediate vicinity of the tributaries. The fact that Stations 2 and 4 do not reflect the poor water quality of Cascade Creek and Mill Creek, and Station 5, that is not near a known source of pollution has high nutrient and heavy metal sediment concentrations strongly supports this theory. The data from Station 4A further demonstrates that the water entering from Mill Creek is adversely affecting the water quality of Erie Harbor, but the dispersal of materials is not uniform throughout the basin.

A study performed by Engineering-Science, Inc. in 1973 determined prevailing winds and general current flow in Lake Erie. Winds are usually from the west, but occasionally from the northeast and water current direction was generally the same as the wind direction. This information is helpful in explaining the water quality of the different stations sampled in this study. Since the currents usually flow from west to east, water from entering tributaries tends to flow along the shore rather than toward the center of the lake. Stations directly north of tributary inputs do not necessarily reflect the quality of the water entering the lake.

The current inside the bay is influenced both by wind direction and shore pattern. When the wind is from the west, the water moves offshore from Presque Isle Peninsula toward the opposite shore and then easterly along the shore out of the bay. When winds are from the northeast, water moves from the lake into the bay which results in a different distribution of substances within the bay. A more precise mapping of currents within the bay is needed to determine the distribution of substances entering the bay and lake.

The dependence of current flow on wind direction may help explain the fluctuations in chemical concentrations. When the wind is from the west, the lake stations are more likely to be affected by the water entering the bay from Mill Creek. A northeast wind causes lake water to enter the bay, and substances entering the bay from tributaries would be retained in the bay at this time. For this reason the chemical concentrations measured at both lake and bay stations may be highly dependent on wind velocity and direction.

There are important implications to this finding. Uniform mixing may not occur from point source discharges into lakes because of current flow patterns. It further implies that the area nearest the emission source may not be the most severely affected area. The results of the present study suggest that the most severely affected area may be Station 5 rather than the areas nearest the industries. One of the reasons for suggesting this possibility is the high concentrations of nutrients and heavy metals in the sediments at Station 5. Sediments have the potential for affecting water quality for an indefinite period of time by supplying the surface water with nutrients and heavy metals.

Another factor may influence the high nutrient and heavy metal concentrations in Misery Bay (Station 5). The bay is very well sheltered from wind and wave action and has a thick growth of aquatic vegetation. Since the bay is sheltered, the nutrients released from the decomposition of this vegetation would be retained in the bay rather than distributed to other parts of the lake. Many aquatic plants also remove heavy metals and are considered effective depolluting agents (Leland et. al., 1974). However, if the plants are not removed, the metals are returned to the sediments as the vegetation decomposes. It has also been demonstrated that bacteria can accumulate certain heavy metals (Leland, et. al., 1974) which would add to metal retention in the sediments. This process would result in accumulation of nutrients and heavy metals in Misery Bay that does not occur in areas that undergo more mixing and have less vegetation.

The effects of heavy metals in the concentrations found in Lake Erie and its tributaries are difficult to evaluate. Extensive information on heavy metals is not available and the conclusions of studies that have been done are often contradictory. Synergistic effects seem to be especially important in regard to heavy metals and partially explain the differences in results of studies. There are also major differences in the toxicity of different metal compounds and the type of organisms that are affected by these compounds. The sulfates of copper are synergistic with zinc, cadmium, and mercury in toxic effects on some fish. It has also been demonstrated that hardness, temperature, and dissolved oxygen concentration may affect the toxicity of some metal compounds. Since calcium reduces the toxicity of zinc, zinc is toxic in lower concentrations in soft water than in hard water. Lead is inhibitory to bacterial decomposition of ogranic matter in concentrations of 0.1 to 0.5 mg/l. This inhibition could alter the chemistry of the bottom sediments. Some heavy metals, such as mercury and lead, are concentrated in biological systems and others such as copper are not, further complicating the determination of minimum toxic concentrations. For these reasons, the effects of the heavy metal concentrations in Lake Erie are difficult to evaluate. Another problem in assessing the environmental effects of heavy metals is that toxicity studies are usually based on LC 50 values which do not take into account growth rate changes or avoidance behavior in organisms.

The complexity of the problem of heavy metals restricts this analysis to general trends rather than a detailed analysis of the significance of the concentrations of each heavy metal measured. The concentration of the most abundant heavy metals in the lake were not high enough to definitely indicate toxicity without information, beyond the scope of this study, on chemical parameters and the type of metal compounds present. In Cascade Creek and Mill Creek, the mean concentrations of copper, lead, zinc, and aluminum were above the levels established by the EPA.

There is less information on the significance of heavy metals in the sediments than on concentrations in water. Aluminum and iron are known to be tied up in the phosphorus cycle and affect the solubility of phosphate compounds, but the question of toxicity has not been sufficiently studied. Although it is a concern in regard to the shellfish industry, the emphasis is on human consumption of heavy metals rather than on changes in benthic biota.

Past Studies

Information on the earlier water quality of Presque Isle Bay is available from previous studies. A comparison of the present water quality with that reported in a 1972 study by Aquatic Ecology Associates indicates there has been an improvement in some aspects and a decline in others. Ammonia and orthophosphate concentrations have decreased. The highest ammonia concentration measured in the bay in the present study was 0.32 mg/l in contrast to values in excess of 0.6 mg/l in 1972. The maximum orthophosphate concentration measured was 0.23 mg/l in 1972, and 0.03 mg/l in 1974. The present biochemical oxygen demands were higher than in the 1972 study. Biochemical oxygen demand increased from a high of 4.0 mg/l in 1972 to mean values above 5.4 mg/l in 1974. Total solids, specific conductivity, and pH did not show any changes.

The present water quality, when compared to the 1972 and 1973 studies performed by the Great Lakes Research Institute (GLRI), showed that phosphate concentrations in the two studies were similar. Heavy metal determinations were higher in the present study than in the 1973 study for mercury, lead, iron, aluminum, and chromium. Copper concentrations were lower and cadmium was the same. Bacteria concentrations are difficult to compare due to fluctuations that are often dependent on weather conditions and seasonal changes. Overall total and fecal coliform bacteria concentrations in the lake were higher in the present study than in the 1973 study. A greater difference between the lake and bay was observed in the Great Lakes Research Institute studies than in the present study. Since the earlier study was conducted during the summer and this study was performed over the winter and spring months, seasonal patterns may be the reason for the difference. The differences between bay and lake water quality that were observed in the present study were greater in the fall and spring. This indicates that during warm weather months there is a difference in water quality between the bay and lake, with the lake having better water quality.

A comparison of the benthic data of this study and the GLRI study was not possible because of different analytical techniques. The benthic analysis by Aquatic Ecology Associates was comparable for several parameters. The sediment concentrations in the bay for copper, zinc and nitrogen were all similar. Phosphate concentrations in 1974 were higher and lead concentrations were lower than those recorded in the 1972 study.

Plankton numbers are extremely difficult to compare since there are many different collection and concentration techniques as well as variation between individual counters. The consistently lower plankton numbers in this study reflect these differences in collecting and counting techniques, especially with regard to counting colonial forms of algae. In this study, colonial algae were counted as colonies.

GLRI Studies

The 1973 GLRI report indicated little difference in the water quality between points east and west of Erie, Pennsylvania. According to the report, the pollutant input level in the Erie area is not sufficient to adversely affect the water quality of Lake Erie. The report indicated that both the 1972 and 1973 physical parameters were indicative of good water quality. Dissolved oxygen levels were observed in both 1972 and 1973 to remain near the saturation level throughout the study area. A slight improvement was observed from 1972 to 1973.

Coliform bacteria were not detected at beach or open lake stations, but coliform bacteria were measured in Presque Isle Bay and the outer harbor. Cyclic increases in coliforms were observed, with peaks in June and September.

The 1972 and 1973 results indicated that water quality in the localized area of Presque Isle Bay is not improving. Results indicated that in the Bay region the levels of algae, zooplankton, coliform, aluminum and iron are significantly higher than in the lake. Benthic deposits of lead, iron, orthophosphate and total phosphate were twice as high or higher than elsewhere along the Pennsylvania shore of Lake Erie.

Aquatic Ecology Associates Study

Aquatic Ecology Associates (1973) performed a comprehensive ecological study of Presque Isle Bay for the Pennsylvania Electric Company. Field studies were conducted from the winter of 1971 to the summer of 1972. The study included the analysis of physical and chemical water quality parameters, plankton, chlorophyll a and chemical and biological constituents of the sediments.

The dissolved oxygen concentration and percent saturation fell drastically in the inner boat basin area during the winter months. This fluctuation was directly related to the influx, death and egress of the gizzard shad within the inner basin. The shad begin to run into the basin area during September and reach a peak in January. In March their numbers begin to decrease and by April the shad population approximates that of the summer months. There is a gradual die-off of shad beginning in December. Decomposition of the fish results in oxygen consumption and the production of substantial amounts of ammonia and phosphates. Nitrate levels were also elevated during the winter months as a result of the shad decomposition. Thousands of gulls are usually present during the winter months to feed on the dead shad (which float to the surface after initially sinking to the bottom). Defecation from these birds is substantial and adds to the ammonia and nitrate levels.

Hammermill Paper Company Studies

In May, 1972, the Hammermill Paper Company initiated a limnological study of Lake Erie waters surrounding the Erie division plant. Results of the study indicated that improvements in color, BOD and dissolved oxygen have occurred since the implementation of a new pulping process (Neutracel II process) in May of 1971. From 1971 to 1972, average levels of color, BOD, phosphate and temperature in the lake decreased. Average color levels went from 29.8 units in 1971 to 18.4 units in 1972; BOD decreased from 6.6 mg/l in 1971 to 4.3 mg/l in 1972; phosphate decreased by 50 percent from 0.50 to 0.25 mg/l. Dissolved oxygen levels increased from 6.6 to 7.6 mg/l.

Color levels in the surrounding lake area were still affected by the Hammermill discharges. Color increases ranged both upstream and downstream of the plant.

Dredge and Fill Operation

As mentioned above, the U.S. Corps of Engineers plan to use dredged materials to fill the portion of the lake southwest of Station 7 and northeast of the sewage treatment plant. The water quality at Stations 7 and 8 is good and may be affected by the transport of dredged materials from the proposed fill area. Although the prevailing currents are in a southeasterly direction, heading away from Beach 11 (Station 8), water movement is extremely variable and is directed by wind action. If the proposed fill project is not properly operated, it is probable that the water quality at Beach 11 will be degraded, impairing its recreational use.

SECTION VIII
GARRISON RUN SURVEY

Introduction

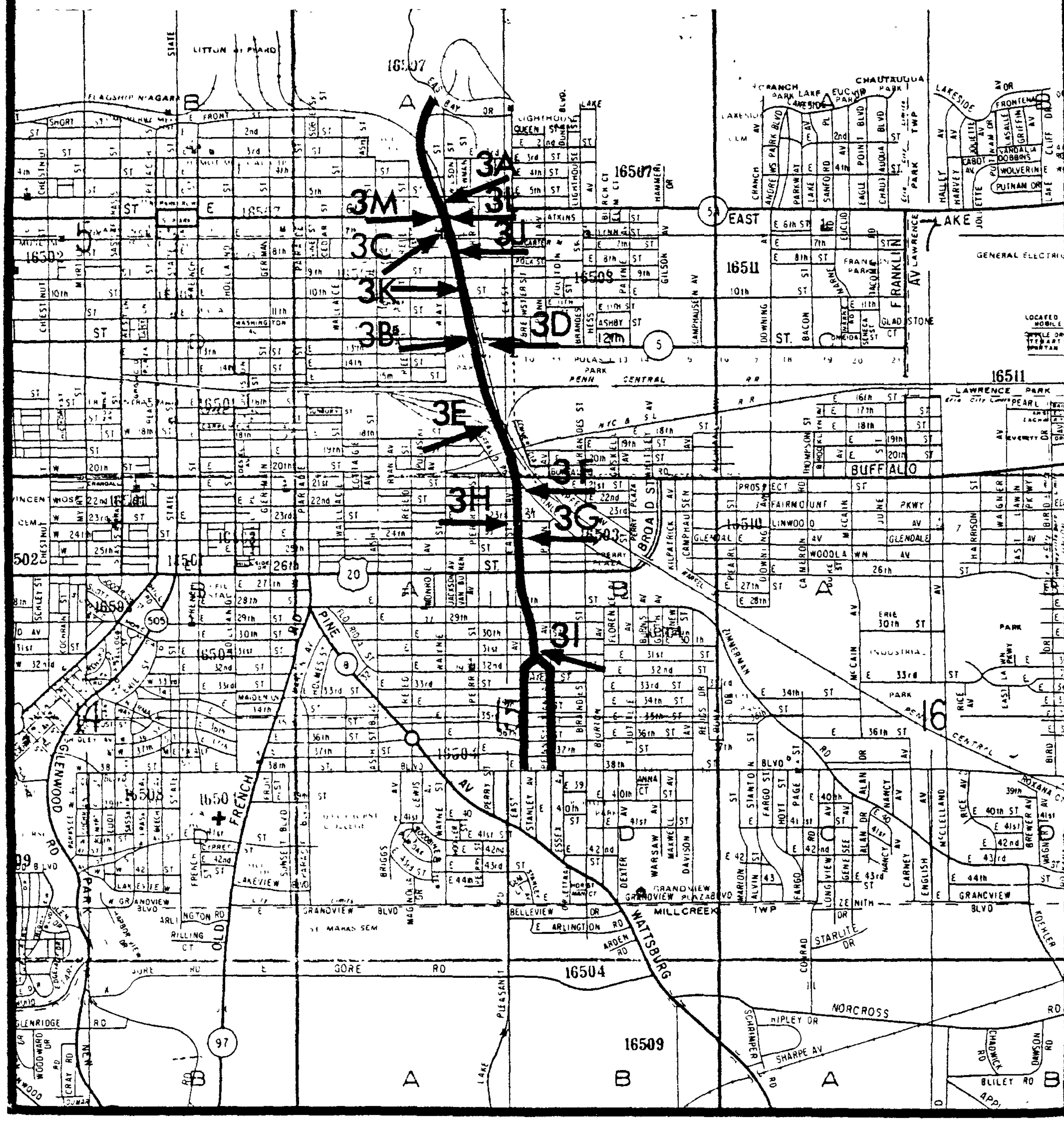
Garrison Run is a combined natural stream and storm sewer made up partially of a structural tube and open drainage channel that runs along East Avenue and Wayne Street in a south to north direction for approximately two miles and empties into Presque Isle Bay. The location of Garrison Run is illustrated in Figure 13. Although Garrison Run is used as a storm sewer, it also conveys a continuous flow from a small, natural drainage stream. In addition, combined sewers along this section of the city overflow into Garrison Run during periods of peak flow (Dalton, Dalton and Little, 1971). The tube collects storm drainage from as far south as 38th Street to as far north as 5th Street and Wayne. At this point, the storm water flows through an open channel in a northerly direction to 3rd Street. Just north of the Pennsylvania Soldiers and Sailors Home between 2nd and 3rd Streets, Garrison Run is again enclosed in a tube which discharges directly into Lake Erie, downstream to the municipal sewage treatment plant.

The tube varies from 72 to 96 inches in diameter and is constructed of concrete or tile depending on the age of the section. The open channel portion of the run has a variable width ranging from a minimum of about 8 feet to a maximum of 18 feet at the 5th Street outfall.

At one time, many industries along the Garrison Run watershed discharged their process waters into the tube. In 1953, Erie City officials from the City Engineering Department made a field inspection of the tube to determine the location of all industrial discharges to the tube. At that time, City officials made the local industrial dischargers disconnect from the tube. However, it is believed that some industrial wastewaters, in particular intermittent discharges, are still being discharged into Garrison Run.

The purpose of the Garrison Run survey was threefold: (1) to determine the location of all discharges into the Garrison Run tube; (2) to determine the actual condition of the conduit; and (3) to determine if any of the discharges contain industrial or municipal wastewater. A point source survey was performed by visual inspection of the tube. Sources of flow into Garrison Run tube were determined and wastewater samples from each of these sources were collected, preserved, and analyzed for relevant wastewater parameters. Intermittent discharges into the tube were also monitored and sampled. Flow rates

FIGURE 13
GARRISON RUN SURVEY
LOCATION OVERVIEW MAP



were measured wherever possible by the "bucket and stopwatch" method. Special sampling devices were placed in specific discharge outlets in order to collect samples of intermittent or fugitive discharges. These devices were periodically checked to determine whether a discharge had occurred.

After completion of the visual field inspection, a complete inventory of all discharges into Garrison Run was prepared. This inventory included a precise location map of all point discharges, the apparent source, flow rates, flow characteristics, and type of tie-ins to Garrison Run.

After review of all collected data, it was verified that some industries are discharging wastewater into the tube. An effort was made to determine those industries suspected of discharging into Garrison Run. This task was designed to provide additional and useful information to appropriate local, state and federal officials so that the pollution problems within Garrison Run could be appraised and remedied. Although in many cases the exact industrial polluter could not be identified, the location map prepared from this study defined the general area of the industrial discharge.

Past Inspection of Garrison Run

As previously mentioned, Erie City Engineering Department officials made a field inspection of Garrison Run on August 22, 1963. The survey team began the inspection at the north end of the run next to the Soldiers and Sailors Home and proceeded south.

In general, the tube was found to be of either tile or concrete construction with a diameter of either 78 or 96 inches. Structurally, the tile pipe was in fair condition, having many broken tiles along the bottom invert. The tile portion of the run extends between 5th and 12th Streets. Accessibility in this portion of the sewer was impossible because of grease and slime growth layers on the bottom invert.

The concrete portion of the tube extends from 12th Street to 31st Street and was in excellent condition. No sediment and very little erosion was observed in this portion of Garrison Run.

Water from Garrison Run was analyzed in January and February of 1963 by the City of Erie Engineering Department. Results of these analyses are presented in Table 8. The slime layers and foul odors observed in 1963 along with visual inspection of the stream indicated definite traces of sanitary and industrial wastes. However, most of the stream flow was from non-polluting sources.

TABLE 8

ERIE CITY ENGINEERING DEPARTMENT

WASTE CHARACTERISTICS OF GARRISON RUN OUTFALL*

		Concentration as mg/l unless noted otherwise		
Sample Date	BOD_5	Suspended Solids	Alkalinity as $CaCO_3$	pH
1/21/63	--	26	80	7.3
1/26/63	--	206	140	7.3
1/28/63	7	12	140	7.3
2/2/63	--	6	160	7.3
2/4/63	--	8	160	7.0
2/9/63	--	12	140	7.0
Average:	7	45	137	--

* Sample location at 5th Street

Results of the 1963 survey are summarized in Table 9. All storm, sanitary, and industrial discharge connections to Garrison Run were identified with respect to location and type of tie-in. The purpose of this investigation by the City of Erie was to seal-off or disconnect any industrial or sanitary discharges that flowed into Garrison Run. Immediate steps were undertaken to insure that all connections would discharge only storm water.

Combined Sewer Study

In December, 1971, the consulting firm of Dalton, Dalton and Little was commissioned by the City of Erie to conduct an engineering study and prepare a report on the location and quantity of the combined sewer discharges and overflows within the City of Erie. The study was authorized by City Council resolution of July 22, 1970. It was determined that the older section of the city extending from the lakefront south to 28th Street was originally provided with a combined storm sewer system. This system was intended to handle all types of wastes: sanitary, storm runoff, building footer drains, and roof drains. Overflows were installed in the system over the following years to provide the necessary relief to protect the area from flooding during periods of excessive flow. From the contractor's investigation, seven combined sewer overflows were found to be connected to Garrison Run (Dalton, Dalton and Little, 1971). According to the contractor's report, it appeared that all of the overflows were not provided with the original sewers, but were later added to the system.

It was determined that the total pollution load discharged annually from combined sewer overflows is in the order of:

806,000 pounds of Suspended Solids
128,000 pounds of BOD
1,700 pounds of Phosphate as P

It was estimated that roughly 25 percent of this load discharged to Garrison Run. Therefore, a rough estimate of the annual combined sewer overflow to Garrison Run is in the order of:

201,000 pounds of Suspended Solids
32,000 pounds of BOD
1,700 pounds of Phosphate as P

These loadings were determined by assuming a defined average storm (which occurs 75 times per year) and applying pollutant parameters for sanitary and industrial wastes (Dalton, Dalton and Little, 1971).

TABLE 9

ERIE CITY ENGINEERING DEPARTMENT
FIELD INVESTIGATION OF GARRISON RUN - SUSPICIOUS DISCHARGE SOURCES

Designation Number	Location	Diameter of Connection	Type of Connection	Discharge Type	Date Investigated
1	Vicinity of 6th Street	24"	--	Sanitary	8/28/63
2	94 Feet north of 9th Street	8"	--	Hot Water	8/28/63
3	Between 10th and 11th Street	6"	cast iron	Sanitary	10/1/63
4	East of 10th Street	12"	tile	Sanitary	10/1/63
5	Between 9th and 10th on west side of tube	4"	--	None	10/1/63
6	Between 8th and 9th on west side of tube	6"	--	Sanitary	10/1/63
7	Between 8th and 9th on west side of tube	54"	concrete	Storm	10/1/63
8	Between 8th and 9th on east side of tube	12"	--	Storm	10/1/63
9	58 feet north of 11th Street	4"	--	Sanitary	8/28/63
10	160 feet north of 11th Street	15"	--	Storm	8/28/63
11	South of 12th Street on east side of tube	8"	tile	Industrial and Sanitary	8/28/63
12	At 28th Street	18"	tile	Sanitary Overflow from Inverted Syphon	8/28/63
13	5 feet north of 23rd Street on east side of tube	20"	--	Sanitary	8/28/63

* Other connections are definitely storm sewers and have not been listed.

The location of the combined sewer overflows into Garrison Run, as reported, are summarized in Table 10. The contractor determined that elimination of all combined sewer overflow locations discharging into Garrison Run including all ancillary components would cost an estimated $14,000,000. Because of the extent and high initial cost of the program, it was recommended by the contractor that the existing combined sewer system, originally installed in the old section of the city, should be retained.

Point Source Survey of Garrison run

The present field investigation of Garrison Run took more than three months to complete. During this period, efforts were made to sample each discharge, herein referred to as station, two or three times whenever possible.

The survey team initially walked the entire length of the tube from 5th Street to 31st Street to determine the exact location of all connections and to determine the structural condition of the tube. After this initial survey of the tube, 13 stations were selected for in-depth monitoring with Garrison Run. These stations were selected based on visual evidence of sources of wastewater discharge to the tube.

A second trip through the storm sewer was performed to collect grab samples of all dry-weather continuous discharges and to measure the station flow rates. During the second trip, composite samplers were positioned at conspicuous stations, that is, stations believed to be discharging intermittent flows. These samples were then investigated and collected within 48 hours. Samples were also taken at varying locations downstream of the tube opening at 5th Street.

At each sampling station, samples were collected in plastic-one liter containers, stored and transported under proper conditions (e.g., preservatives, ice, etc.), and analyzed for relevant parameters at one of three laboratories. Church Laboratories, a local analytical laboratory from Fairview, Pennsylvania, analyzed one set of samples for biological characteristics while either the Environmental Protection Agency Field Laboratory at Charlottesville, Virginia or Betz Laboratories at Trevose, Pennsylvania analyzed the other samples for physical and chemical parameters. For each sample the following analyses were made to effectively determine the character of each non-storm water discharge into Garrison Run.

BOD_5	Ammonia
Total Plate Count	Nitrate
Total Coliform Count	Nitrite
Fecal Coliform Count	Total Iron
Color	Copper

TABLE 10

SUMMARY OF GARRISON RUN COMBINED SEWER OVERFLOWS

Location	Type	Dry Weather Flowrate (mgd)	Overflow Flowrate (mgd)
4th and Ash	Side Channel Weir	1.66	22
East Ave. and Commercial	Siphon with over-flow pipe	2.3	-
23rd between East and Penna.	Siphon with over-flow pipe	.16	1.3
25th and Brondes	Overflow pipe	.06	1.17
28th-East & Penna.	Siphon with over-flow pipe	.003	1.1
32nd & East Avenue	Overflow pipe	.36	1.3
24th and Penna.	Splitter	.14	-

pH	Aluminum
Alkalinity	Zinc
Specific Conductance	Chromium
Total Phosphate	Lead
Ortho Phosphate	Cadmium
Total Solids	Mercury
Suspended Solids	

Visual Inspection of Garrison Run

The survey team entered the tube at 5th and Wayne Streets. At this point, accessibility into the tube opening was difficult because of construction debris retarding the stream flow. Most of the debris emanated from the adjacent lumber yard. In addition, oil and grease material was visible on the water surface, being retained by the debris.

The tile portion of the conduit (from 5th and 12th Streets) appeared to be structurally sound although many bottom invert tiles were broken. Sections of broken tiles were as long as 100 feet in some areas. The bottom invert of the tile sewer was coated with slime growth layers, but no bottom sediments were observed. Samples in this portion of the conduit were collected at:

Station	Location
3A	5th Street opening (Garrison Run confluent)
3L	Between 5th and 6th Streets on the east side
3M	Between 5th and 6th Streets on the west side
3J	Between 6th and 7th Streets on the east side
3C	Between 6th and 7th Streets on the west side
3K	Between 9th and 10th Streets on the west side
3D	Between 10th and 11th Streets on the east side
3B	At 12th Street on the west side

The location of these stations is presented in Figure 13, on page 86. All stations sampled were either flowing at the time or appeared to have had intermittent flows. There were no sanitary flows or evidence of sanitary sewage in this portion of the tube. All sanitary connections identified in the 1963 City of Erie Engineering Department Survey were found to be effectively sealed. In addition, the musty smell that was noticed between 5th and 6th Streets during the 1963 inspection could not be detected during this investigation.

The concrete portion of the 98" diameter storm sewer begins at 12th Street, reduces in size to 78" diameter at 24th Street and terminates at 38th Street. The concrete tube is in excellent condition with very little deterioration. The bottom invert is slightly eroded with some sediment deposits. No slime growths were evident.

Adjacent to the Wayne Street Railroad Yard between 15th and 18th Streets, an oily musty smell could be detected. At about 18th Street, the old Garrison Run tube was found; its location is shown on the Location Maps presented in Figure 14.

At approximately 26th Street, an odor of sanitary sewage could be detected. It appeared that the sewage may be emanating from an inverted syphon overflow although it was not flowing during our survey. This connection, located at 28th Street, was also identified during the 1963 inspection.

Samples in this portion of the conduit were collected at:

Station	Location
3E	Wayne Street Railroad Station manhole between 15th and 18th
3F	21st and 22nd Streets on the east side
3G	23rd Street on the east side
3H	23rd Street on the west side
3I	30th Street (Garrison Run confluent from natural drainage stream)

These stations are also shown in Figure 13.

In total, fourteen stations were sampled. A complete inventory of the sampling stations including flowrates, flow characteristics, types of connections, and locations is presented in Table 11. An overview map showing all connections is presented in Figure 14.

Water Quality Analysis

A complete analysis for each sample station is provided in Table 12.

From Table 12, it may be concluded that some of the connections to the Garrison Run tube are discharging contaminated effluents which subsequently reach Presque Isle Bay. Each of the parameters analyzed were used to assess the strength and character of the discharges. Evaluation of the parameters were performed to determine whether the discharge was characteristic of a domestic (sanitary) or industrial wastewater.

Color

The U.S. Public Health Service has established a color limit of 15 units for waters intended for human use. From Table 4, it would appear that Stations 3C, 3H, 3K, and 3L were highly colored and may be associated with sanitary or industrial wastewaters.

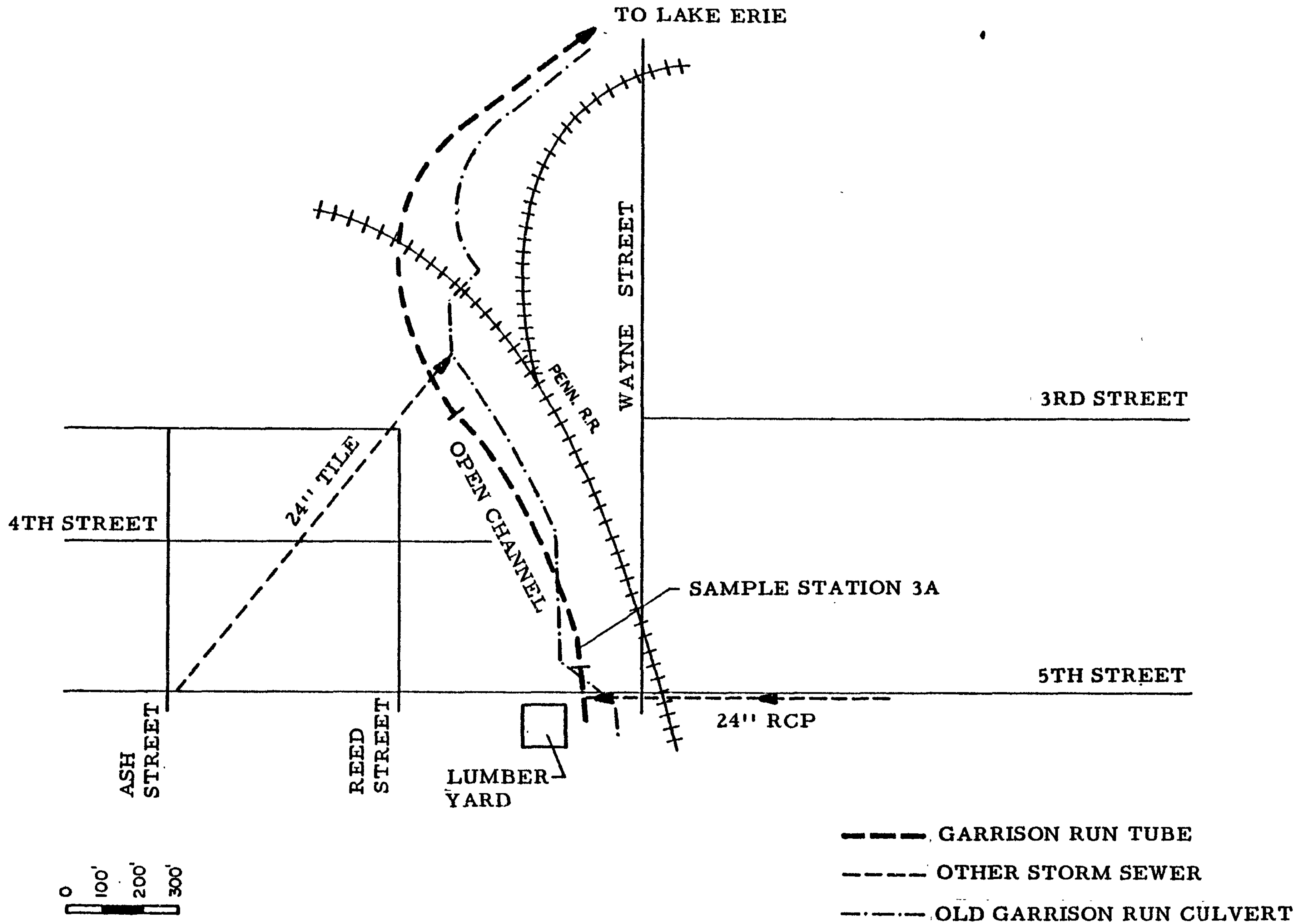


FIGURE 14

GARRISON RUN LOCATION MAP

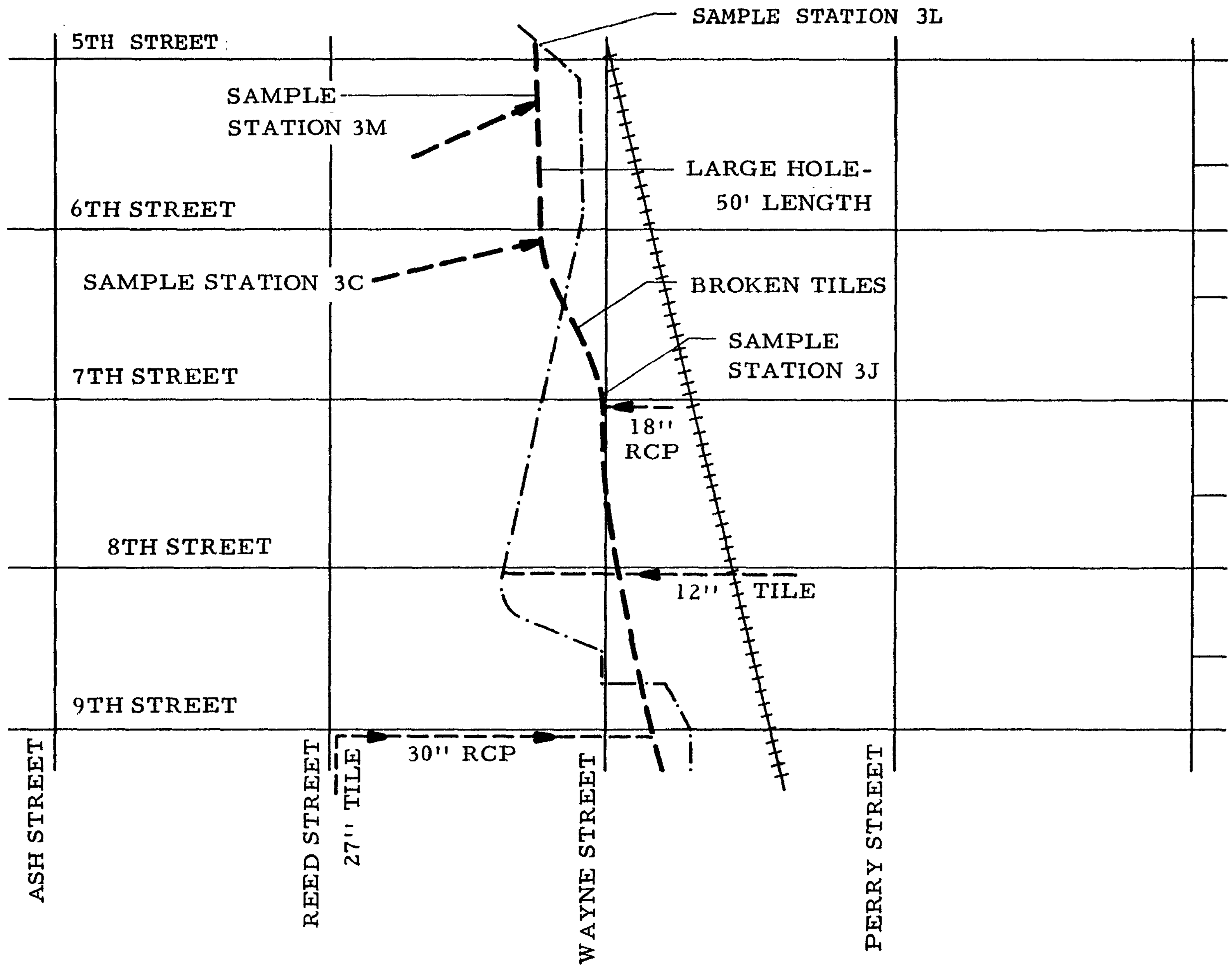


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

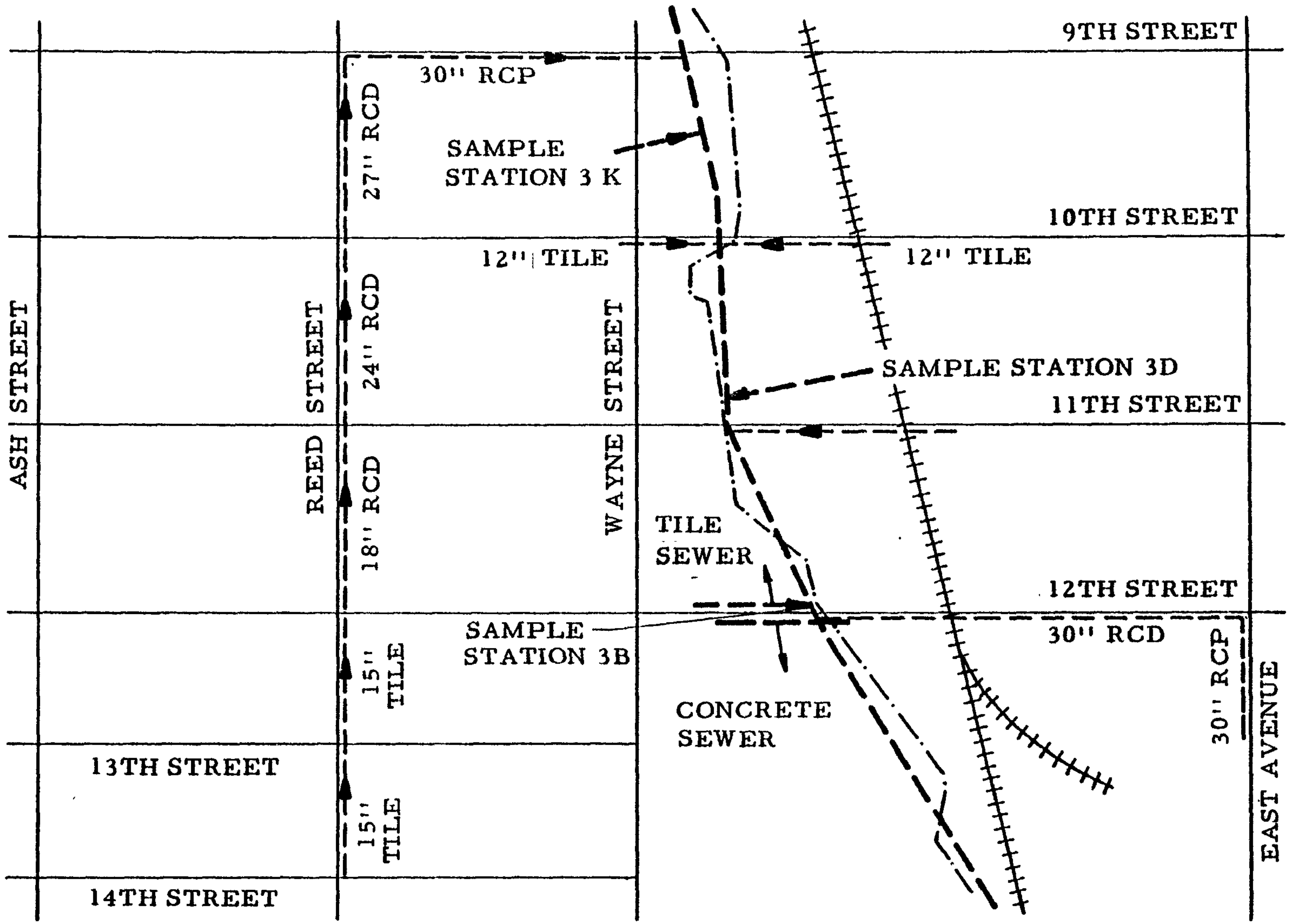


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

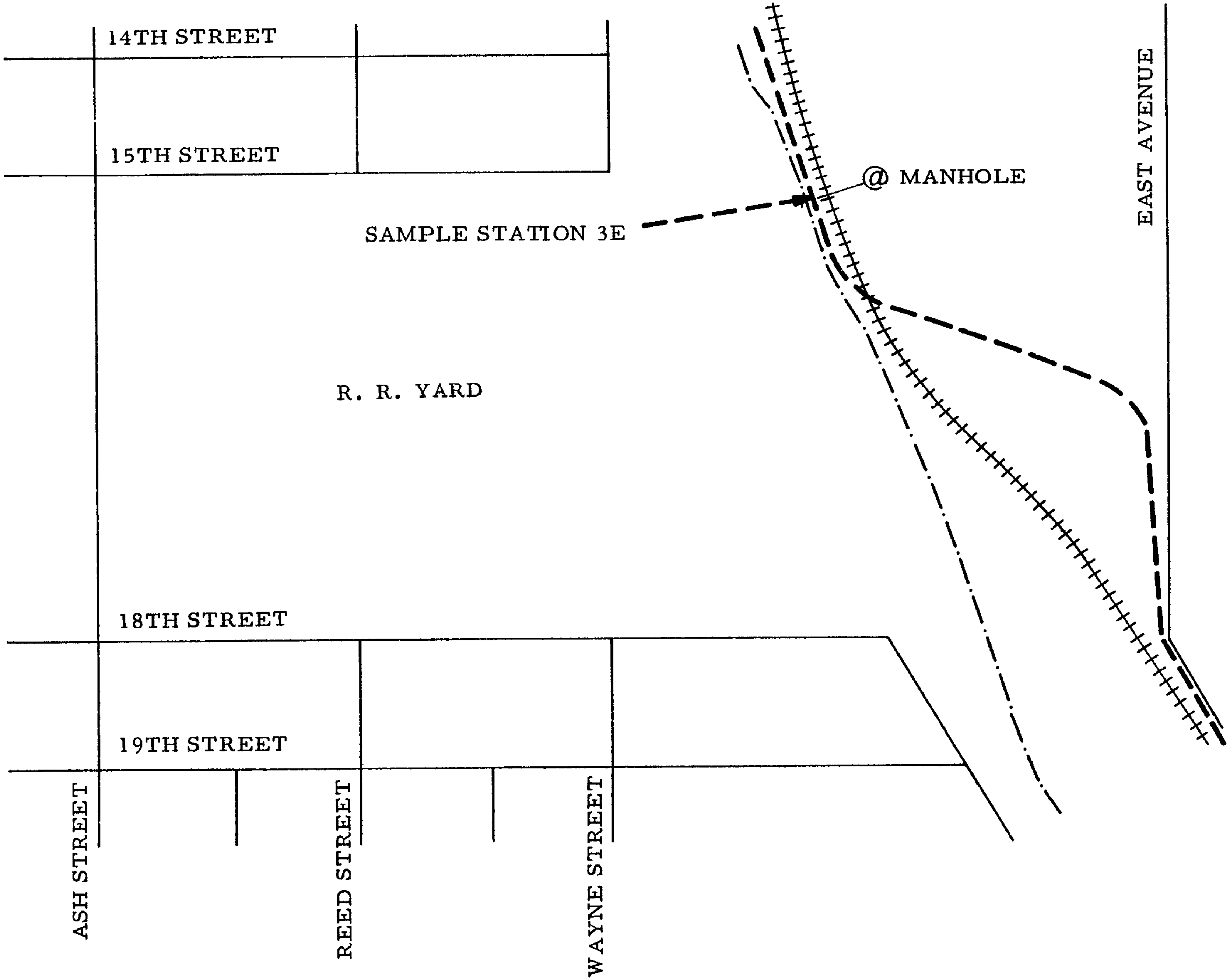


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

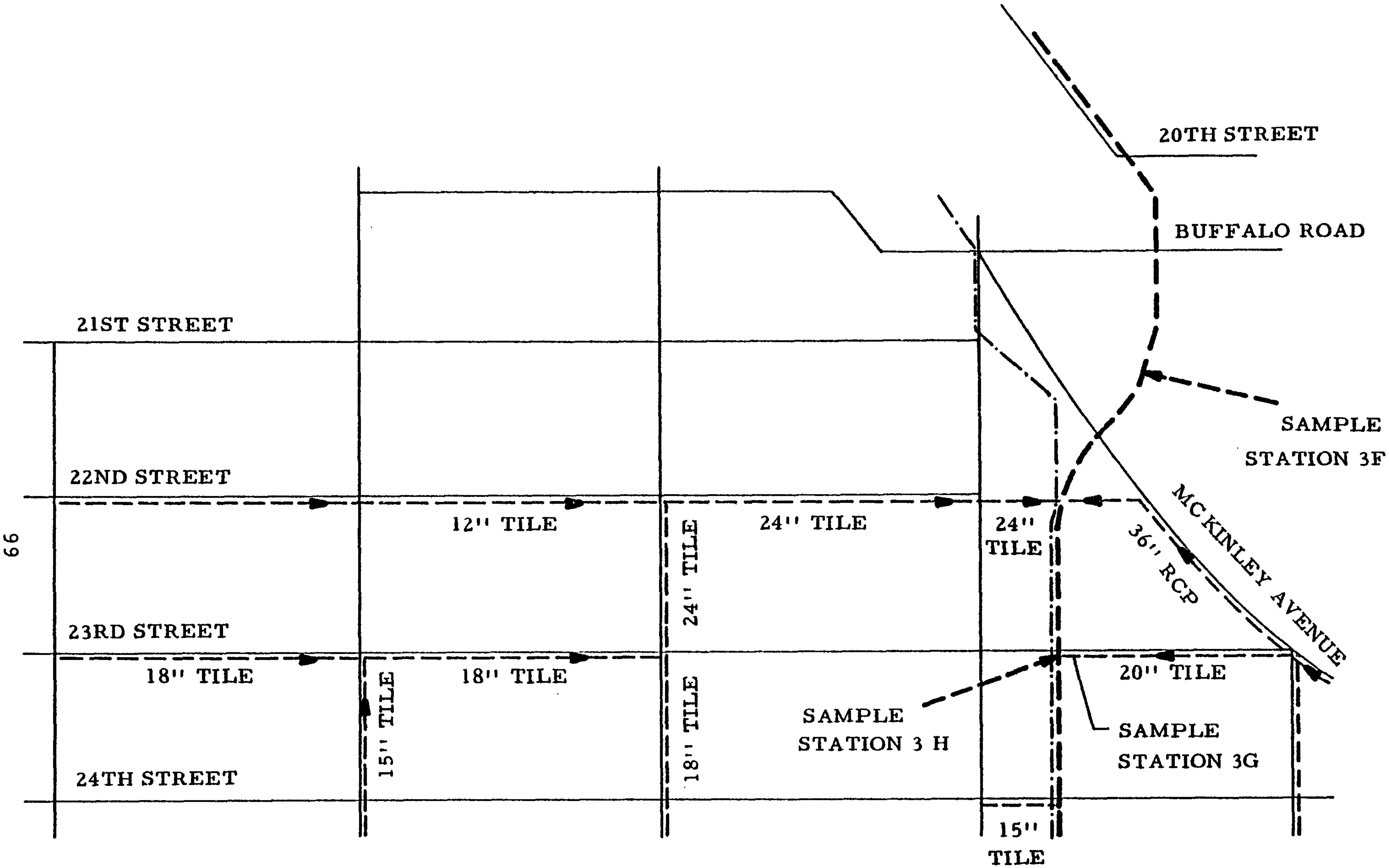


FIGURE 14 (cont'd)

[illegible] RUN LOCATION MAP

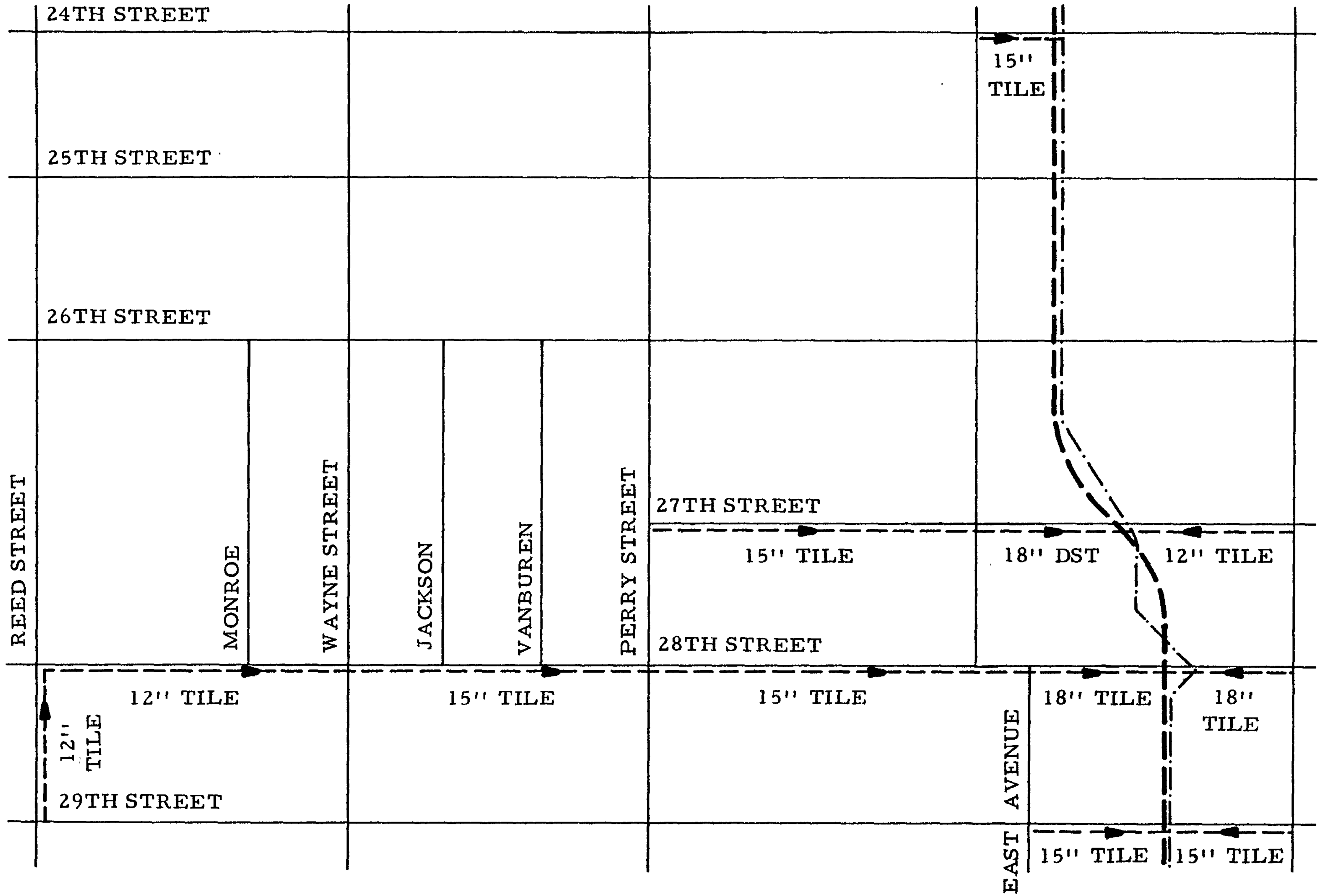


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

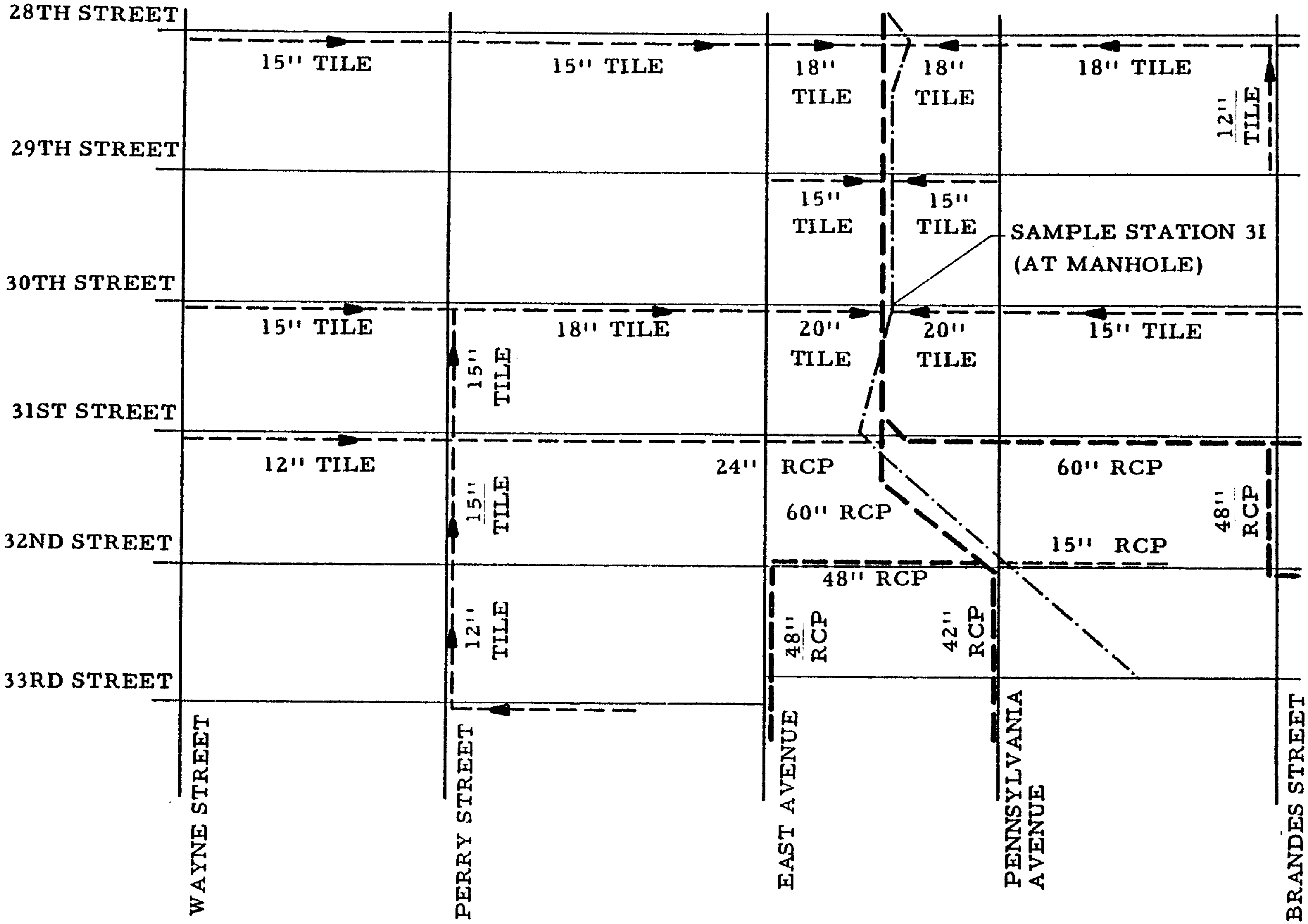


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

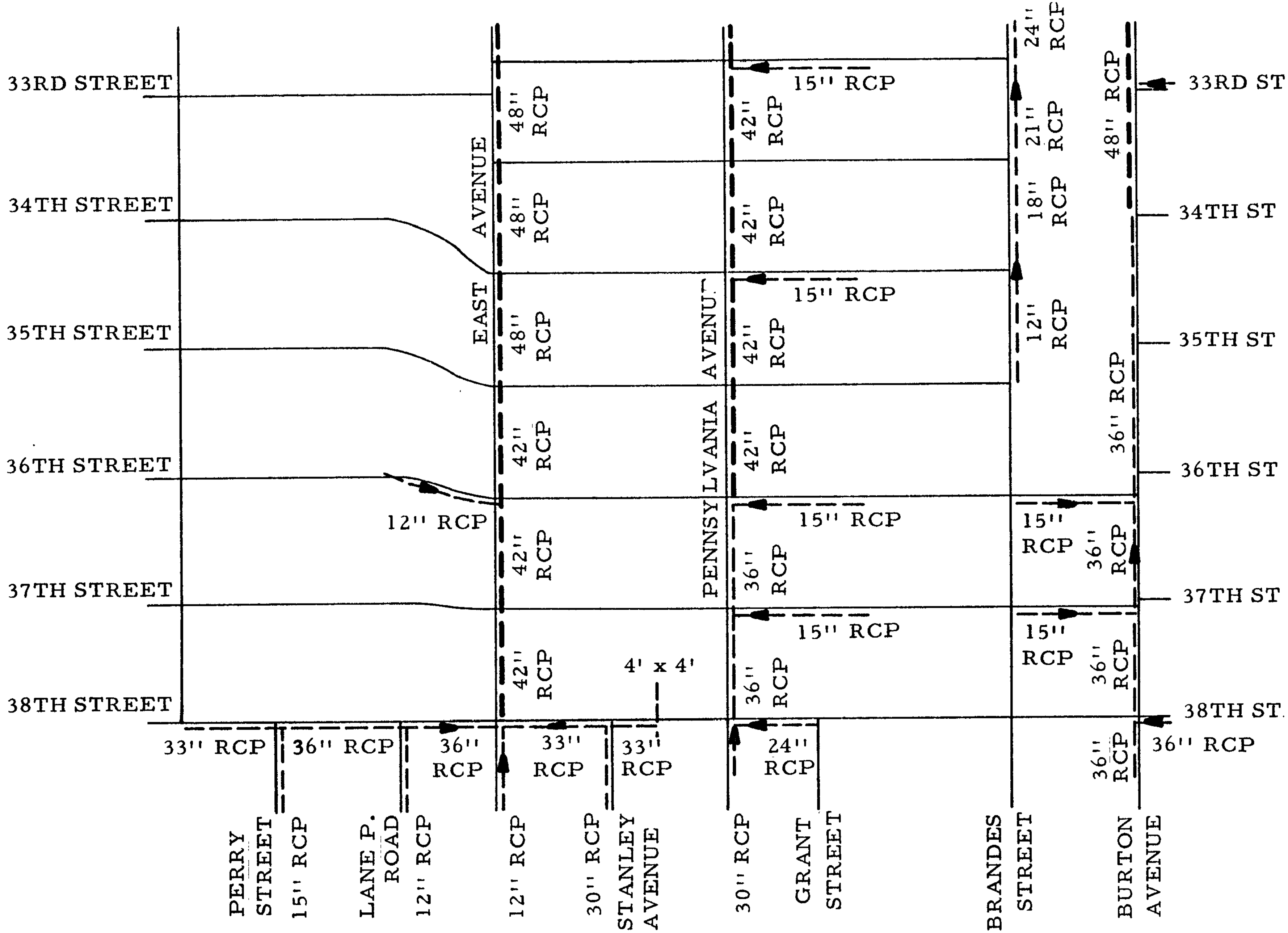


FIGURE 14 (cont'd)

GARRISON RUN LOCATION MAP

TABLE 11

FIELD INVESTIGATION OF GARRISON RUN - DRY WEATHER DISCHARGE SOURCES

Designation Number	Location	Discharge Type	Station Pipe Diameter	Flow Rate (gpm)	Type of Connection
3-A	Tube opening at 5th Street	continuous	--	--	tile
3-B	12th Street - west side	continuous	18"	4.6	--
3-C	Between 6th & 7th Street, west side	continuous	48"	15	concrete
3-D	Between 10th & 11th Street, east side	continuous	15"	8.0	--
3-E	At Wayne Street Station manhole (15th & 18th St.)	continuous	24"	150*	concrete
3-F	Between 21st and 22nd Street, east side	continuous	30"	2.5	concrete
3-G	23rd Street, east side	continuous	36"	7.5	concrete
3-H	23rd Street, west side	intermittent	24"	--	cast iron
3-I	At 30th Street (confluent to tube)	continuous	--	75*	concrete
3-J	Between 6th & 7th, east side	continuous	18"	1.5	tile
3-K	Between 9th & 10th Street, west side	intermittent	30"	--	concrete
3-L	Between 5th & 6th Street, east side	continuous	48"	25*	concrete
3-M	Between 5th & 6th Street, west side	continuous	24"	14	tile

* Estimate

TABLE 12

GARRISON RUN WATER SAMPLE ANALYSES

	Station Designation Number								
	3A			3B		3C		3D	
pH, units	7.71	7.03	--	7.6	7.16	7.14	--	6.88	7.7
Color, units	40	5	10	2	10	1	100	1	10
BOD_5	31	12	30	2	5	8.1	2	8	9.0
Total Plate Count Col/ml	18,200	19,000	738,000	2,000	35,000	310,000	7,300	350	70,000
Total Coliform Count Col/100 ml	50,000	23,400	61,000	300	500	74,000	500	100	430
Total Fecal Count Col/100 ml	170	160	7,200	10	800	770	10	10	--
Alkalinity, as $CaCO_3$	87	116.1	--	142.4	140	--	--	86.5	90
Total Solids	487	391	--	520	454	296	--	249	170
Suspended Solids	232	8	--	5	5	4	--	2	4
Ammonia-N	.165	.54	.50	.31	.16	.31	.50	.29	0.3
Nitrate-N	.995	.995	3.6	1.733	2.5	.874	.40	.646	1.3
Total Kjeldahl Nitrogen	--	.572	--	.450	--	.44	--	.86	--
Nitrite-N	.039	.485	--	.095	--	.124	--	.11	--
Total Phosphate, PO_4	.63	.10	1.2	.003	1.2	.60	1.4	.07	1.2
Dissolved Phosphate, PO_4	.04	.02	--	.018	--	.39	--	.04	--
Ortho Phosphate, PO_4	--	--	80	--	1.0	--	1.0	--	1.0
Total Iron, Fe	14.11	.62	.50	.426	6.0	.26	6.6	1.040	.30
Cadmium, Cd	.0028	.021	.01	.0002	.01	0	.01	.00004	.01
Copper, Cu	.042	.014	.02	.006	.01	.008	.10	.04	0
Zinc, Zn	.252	.037	.10	.077	.10	.035	.10	.177	0
Total Chromium, Cr	.01	.004	0	.004	0	.004	0	.006	0
Chromate, as CrO_4	--	--	--	--	--	--	--	--	--
Aluminum, Al	7.04	.15	.17	.12	.60	.10	3.5	.30	.30
Lead, Pb	.334	.015	.01	.027	.02	.023	.01	.053	.01
Mercury, Hg	.0052	.0007	.002	.0007	.0074	.0002	.001	.0003	.0061
Specific Conductance, microhmos-18°C	361	530	500	735	600	450	375	375	375
Specific Conductance, microhmos-25°C	--	--	590	--	710	--	440	--	440
Oil and Grease	--	--	11.0	--	--	--	--	--	--
Date Sampled: ________, 1974	5/9	5/22	6/5	5/21	6/5	5/21	6/5	5/22	6/21

TABLE 12 (cont'd)

GARRISON RUN WATER SAMPLE ANALYSES

	Station Designation Number												
	3E		3F		3G		3H	3I		3J	3K	3L	3M
pH, units	6.84	7.3	6,89	7.6	7.75	8.0	6.75	7.69	7.9	7.4	7.7	7.6	7.9
Color, units	3	15	2.5	8.0	5	20	100	1	20	30	150	110	8
BOD_5	57	0	10	4.0	6	1	116	5	2	6	37	61	0
Total Plate Count Col/ml	20,000	1,390,000	42,000	11,000	11,600	6,800,000	360,000	18,000	151,000	33,000	330,000	2,800,000	8
Total Coliform Count Col/100 ml	7,700	7,300	22,300	2,380	5,500	6 100	10 500	2,910	98,000	1,100	14,000	980,000	10
Total Fecal Count Col/100 ml	10	430	8,500	80	10	470	3,330	2,200	310	140	90	46,300	10
Alkalinity, as $CaCO_3$	106	116	85.5	96	335.5	308	113.9	177.2	192	120	312	210	102
Total Solids	365	318	484	536	107.5	926	531	553	448	298	650	342	164
Suspended Solids	4	6	11	10	6	10	14	10	10	14	216	26	2
Ammonia-N	.50	.40	.33	.30	.50	.50	.65	.62	.26	.30	.70	5.0	.16
Nitrate-N	1.28	2.90	.922	4.3	.107	2.5	.01	.978	.20	1.6	.40	.2	.60
Total Kjeldahl Nitrogen	1.386	--	.832	--	1.96	--	1.12	.70	--	--	--	--	--
Nitrite-N	.22	--	.758	--	.795	--	.671	.352	--	--	--	--	--
Total Phosphate, PO_4	.084	1.5	.21	1.3	.015	.30	.84	.08	1.0	.30	.60	10.3	3.1
Dissolved Phosphate, PO_4	.084	--	.161	--	.018	--	.36	.09	--	--	--	--	--
Ortho Phosphate, PO_4	--	.8	--	1.1	--	.20	--	--	.4	.30	.40	8.2	3.1
Total Iron, Fe	1.31	1.30	.40	1.1	2.054	.40	.62	.71	.80	3.3	87.1	1.9	.10
Cadmium, Cd	0	.01	0	.01	0	.01	0	0	.01	.01	.01	.01	.01
Copper, Cu	.016	0	.022	0	.02	0	.028	.008	.02	.16	.52	.02	.01
Zinc, Zn	.09	.20	.062	.10	.052	0	.10	.035	0	0	.80	.10	0
Total Chromium, Cr	.006	0	.005	0	.012	0	.005	.024	0	0	0	0	0
Chromate, as CrO_4	--	--	--	--	--	--	--	--	--	--	--	0	0
Aluminum, Al	.18	.40	.18	.40	.42	.26	.18	.27	.30	.22	11.8	1.2	7.0
Lead, Pb	.018	.01	.045	.02	.045	.01	.088	.033	.01	.01	1.5	.01	.01
Mercury, Hg	.0003	.002	.0002	.0002	.0001	.0024	.0001	.00015	.0016	.0022	.008	.031	.034
Specific Conductance, microhmos-18°C	484	450	718	750	1430	1100	618	802	350	450	700	600	290
Specific Conductance, microhmos-25°C	--	530	--	885	--	1300	--	--	415	530	825	710	340
Oil & Grease	--	--	--	--	--	--	--	--	--	--	--	--	--
Date Sampled: ________, 1974	5/22	6/5	5/22	6/5	5/21	6/5	5/21	5/21	6/5	6/5	6/5	7/18	7/18

BOD

The BOD_5 of domestic sewage is approximately 100 to 300 mg/l whereas industrial wastewaters vary over a wide range. Using this parameter as the basis, it would appear that effluents from Stations 3E, 3H, and 3L are indicative of a domestic or industrial wastewater that may be diluted.

Total Coliform Count

The Pennsylvania Environmental Water Quality Board has established that no more than 5000 coliforms/100 milliliters as a monthly average can be exceeded, nor more than this number in more than 20 percent of the samples collected during any month, nor more than 20,000/100 milliliters in more than five percent of the samples. All stations, except Stations 3B, 3D, 3J and 3M exceeded the criteria of 5,000 coliforms/100 milliliters of sample. Stations 3A, 3F, 3I, and 3L also exceeded the criteria of 20,000 coliforms/100 milliliters.

Fecal Coliform

The Pennsylvania Environmental Water Quality criteria for fecal coliform is a monthly arithmetic mean value of 200 colonies per 100 ml for water contact sports. All stations except stations 3J, 3K and 3M exceeded these limits.

Alkalinity

The alkalinity of a water has very little pollutional significance; however, the Pennsylvania Water Quality Board has established a criteria limitation for alkalinity, such that it may not be less than 20 mg/l. All discharges into Garrison Run met this criteria.

Suspended Solids

Suspended solids found in considerable quantities are characteristic of domestic and industrial wastewaters. Station 3K had a suspended solids content of over 200 mg/l which increased the turbidity of the water course. Nonetheless, the Pennsylvania Water Quality Board has not established permissive criteria for suspended solids.

Dissolved Solids

The Pennsylvania Environmental Water Quality Board has established that dissolved solids cannot be more than 500 mg/l as a monthly average and not more than 750 mg/l at any time. Station 3G exceeded this limit.

Total Iron

The Pennsylvania Environmental Water Quality Board has established a limit of 1.5 mg/l for total iron and 0.3 mg/l for dissolved iron. Stations 3, 3A, 3B, 3C, 3K and 3L exceeded water quality criteria at least once.

Cadmium

Cadimum has high toxic potential with a concentration of 200 ug/l being toxic to certain fish. Cadmium may enter a water source as a result of industrial discharges or the deterioration of galvanized pipe. No specific water quality criteria exists for cadmium in the Presque Isle Bay area of Lake Erie; however, the California Water Quality Criteria for cadmium is a maximum concentration of 10 ug/l (0.01 mg/l). This limit was not exceeded by any of the samples.

Copper

Copper may be toxic to bacteria and other microorganisms in concentrations as low as 0.1 to 0.5 mg/l. Although not applicable to the Presque Isle Bay area of the Lake Erie Basin, the Pennsylvania Environmental Water Quality Board has established limits for copper. The least stringent criteria is an allowable limit of 0.10 mg/l. Stations 3J and 3K greatly exceeded this limit.

Zinc

Zinc in concentrations above 5 mg/l can cause a bitter astringent taste. Zinc most commonly enters the sewer from the deterioration of galvanized pipe or de-zincification of brass. It may also be a result of industrial pollution. The Pennsylvania Environmental Water Quality Board established criteria for zinc although not applicable to Lake Erie Basin - Presque Isle Bay. The limit of 0.05 mg/l was greatly exceeded in samples from Stations 3A, 3B, 3E, 3K and 3L.

Total Chromium

Chromium as chromate compounds are used extensively in industrial processes and are added to cooling water for corrosion control. Hexavalent chromium has carcinogenic potential and has been limited in potable water supplies. California water quality criteria for total chromium is 0.05 mg/l. This concentration was not exceeded at any of the stations.

Aluminum

Aluminum occurs naturally in minerals, rocks and clays. It may exist as a soluble salt, a colloid, or an insoluble compound. Aluminum in public water supplies is not considered a health problem, but high concentrations of aluminum may be lethal to certain aquatic animals. For this reason, the California Water Quality Commission has established a limit of 50 ug/l (0.05 mg/l) for aluminum. The aluminum concentration at Station 3K was 11.8 mg/l and at Station 3M it was 7.0 mg/l.

Lead

Lead has a cumulative body poison effect. The presence of lead in a water supply may arise from industrial, mine and smelter operations, or dissolution of old lead piping. Although there is no specific criteria for lead in Pennsylvania, the California water quality criteria is a maximum of 50 ug/l. This value was exceeded in samples collected from Stations 3H and 3K.

Mercury

Mercury and mecuric salts are highly toxic to man and aquatic life. It is not likely to occur as a water pollutant, but is used in the manufacture of scientific and electrical instruments, in dentistry, in power generation, in solders, and in the manufacture of lamps. The California Water Quality Commission has imposed a limit on mercury of 10 ug/l. This was not exceeded at any of the stations.

Station Analysis

Stations 3A and 3I

Stations 3A and 3I consisted of Garrison Run water flowing through the tube. Station 3A was located at 5th Street where the Garrison Run tube ended and an open channel began. Except for a combined sewer overflow located downstream of Station 3A at 4th and Ash Streets, Station 3A contained the flow of (1) the Garrison Run stream and (2) all discharges to the tube. The sewer overflow located downstream of Station 3A was not flowing during the survey and thus did not alter the representative nature of Station 3A. Therefore, Station 3A can be considered to be representative of the final water quality of Garrison Run prior to its discharge to Presuqe Isle Bay.

Station 3I on the other hand, was located at 30th Street, upstream of all significant discharges except the overflow pipe located at 32nd Street and East Avenue. However, the overflow pipe was not flowing during the survey. Therefore, Station 3I can be considered to be representative of the water quality of Garrison Run prior to receiving discharges from combined sewer overflows, storm sewers and various industries.

A comparison of the water quality at Station 3A and 3I is provided below to illustrate the effects the various discharges to Garrison Run have upon its water quality.

Garrison Run Water Quality

	Station 3I Upstream	Station 3A Downstream
Color, units	1-20	5-40
BOD, mg/l	2-5	12-31
Fecal Coliform, #/100 ml	310-2200	160-7200
Suspended Solids, mg/l	10	8-232
Iron, mg/l	0.71-0.80	0.50-14.11
Copper, mg/l	0.008-0.02	0.02-0.04
Aluminum, mg/l	0.27-0.30	0.15-7.04
Lead, mg/l	0.01-0.033	0.01-0.33

This comparison indicates that the various discharges to Garrison Run have a significant effect on the water quality within the tube. Color, BOD, suspended solids, iron and aluminum are significantly affected by wastewater discharges to the tube. The relatively high fecal coliform counts measured at Station 3I exceed the Pennsylvania Environmental Quality Board criterion of 200 colonies per 100 ml for water contact sports. These high counts probably result from intermittent discharge of sanitary wastes into the tube from the sewer overflow located upstream of Station 3I.

Station 3B

Station 3B, a continuous discharge located at 12th Street on the west side of the tube had a flow of 4.6 gpm. One of the two samples collected contained fecal coliforms (800/100 ml), orthophosphate (1.0 mg/l), nitrate (2.5 mg/l), iron (6.0 mg/l) and aluminum (0.60 mg/l) in concentrations exceeding natural background levels. These abnormal levels indicate the existence of a small industrial discharge to the tube at this location. The presence of sanitary wastes are also indicated by the measured fecal coliform counts.

Station 3C

Station 3C, a continuous discharge located between 6th and 7th Streets on the west side of the tube, had a flow of 15 gpm. Like Station 3B, the samples collected at Station 3C contained high amounts of color (100 color units), fecal coliforms (770/100 ml), total phosphate (1.4 mg/l), orthophosphate (1.0 mg/l), iron (6.6 mg/l) and aluminum (3.5 mg/l). These levels indicate the possible existence of a small industrial discharge to the tube. Sanitary wastes also appear to be present because of the fecal coliform level measured.

Station 3D

Station 3D is located between 10th and 11th Streets and consists of a continuous discharge of 8.0 gpm through a 15" pipe entering the east side of the tube. Concentrations of nitrate (1.3 mg/l), total phosphate (1.2 mg/l), orthophosphate (1.0 mg/l) and iron (1.04 mg/l) exceeded the background levels for these parameters. However, the measured water quality of this discharge appears to be relatively good and indicates that this discharge consists primarily of uncontaminated storm, process or cooling water.

Station 3E

Station 3E, a continuous discharge located at the Penn Central Wayne Street Station between 15th and 16th Streets, had an estimated flow of 150 gpm entering the tube through a 24" concrete pipe. The discharge contained BOD (57 mg/l), fecal coliform (430/100 ml), nitrate (2.9 mg/l), TKN (1.4 mg/l), total phosphate (1.5 mg/l) and iron (1.3 mg/l) in amounts exceeding natural background concentrations. These concentrations indicate the possible existence of industrial and sanitary wastewater in this discharge.

Station 3F

Station 3F is located between 21st and 22nd Street and consists of a 2.5 gpm discharge into the tube from a 30" concrete pipe located on the east side of the tube. This discharge contained high levels of fecal coliform (8500/100 ml) and nitrate (2.5 mg/l). It also contained suspended solids (11 mg/l), total phosphate (1.3 mg/l), orthophosphate (1.1 mg/l) and iron (1.1 mg/l). The presence of these constituents indicates the possible presence of sanitary and industrial waste discharge to the tube.

Station 3G

Station 3G, located at 23rd Street, is a continuous discharge of 7.5 gpm from a 36" concrete pipe on the east side of the tube. The discharge contained fecal coliforms (470/100 ml), suspended solids (10 mg/l) and nitrate (2.5 mg/l). Except for these constituents the discharge appears to be relatively uncontaminated. The presence of the fecal bacteria, solids and nitrates indicates that a small quantity of sanitary wastes may be entering the tube at this location.

Station 3H

Station 3H is a intermittent discharge entering the tube at

23rd Street from a 24" cast iron pipe located on the east side of the tube. It is believed that this discharge is one of the combined sewer overflows described by Dalton, Dalton and Little (1971). According to their sewer survey report, the dry weather flow through this sewer is estimated at 0.16 mgd and the overflow discharge is 1.3 mgd. However, according to the contractors reports, the overflow is not expected to contribute a flow to Garrison Run on a continuous basin, thus the intermittent nature of the observed flow. It should be noted that the sample collected at this station was obtained by installing a sampling container in the end of the pipe. Visual evidence indicated that the pipe contributed intermittent discharges to the tube.

Station 3H contained high levels of color (100 color units), BOD (116 mg/l), fecal coliforms (3300/100 ml) and suspended solids (14 mg/l). The high BOD to suspended solids ratio indicates a high degree of dissolved organic material. The quality of the discharge indicates that sanitary wastes are overflowing to the tube.

Station 3J

Station 3J consists of a continuous discharge of 1.5 gpm to the tube between 6th and 7th Streets. The discharge contained color (30 color units), some fecal coliforms (140/100 ml), suspended solids (14 mg/l), nitrates (1.6 mg/l) and iron (3.3 mg/l). These constituents indicate that a small industrial waste may be discharging to the tube at this location.

Station 3K

Station 3K, located between 9th and 10th Streets, consists of an intermittent discharge to the tube through a 30" concrete pipe. The discharge was high in color (150 color units), BOD (37 mg/l), suspended solids (216 mg/l), iron (87.1 mg/l) and lead (1.5 mg/l). It appears that this waste originates from industrial processes or from blowdown from industrial process water. Although the industrial discharger could not be determined, it is believed to be within the vicinity of the Garrison Run connection. A list of the nearby industries located on 9th and 10th Streets include:

Industry	Location
Kaiser Aluminum	1015 East 12th Street
Erie Engine & Mfg. Co.	953 East 12th Street
Penn Tool and Die Co.	938 East 12th Street
Salmoa Plastics	810 East 11th Street
Union Iron and Metal	904 East 11th Street
Merro Chemical Co.	827 East 10th Street

Investigation of the specific industries was beyond the scope of work of this project.

Station 3L

Station 3L is located between 5th and 6th Streets and consists of a continuous discharge of an estimated 25 gpm. It contains color (110 color units), BOD (61 mg/l), fecal coliform (46,300/100 ml), suspended solids (26 mg/l), ammonia (5 mg/l), total phosphate (10.3 mg/l), orthophosphate (8.2 mg/l), iron (1.9 mg/l) and aluminum (1.2 mg/l). These constituents indicate a significant discharge of sanitary and industrial wastes at this location.

Station 3M

Station 3M, located between 5th and 6th Streets, consists of a continuous discharge of 14 gpm through a 24" tile pipe. It contained total phosphate (3.1 mg/l), iron (3.1 mg/l) and aluminum (7.0 mg/l), indicating the possible presence of industrial wastes.

Summary

In summary, 13 stations were investigated in Garrison Run. Two of these stations (Stations 3A and 3I) consisted of downstream and upstream portions of Garrison Run stream. Eleven of the stations consisted of continuous and intermittent discharges to Garrison Run. Of these 11 stations, two stations (Stations 3H and 3K) were intermittent discharges; the remaining nine stations consisted of continuous discharges. The highest continuous flows were observed at Stations 3E and 3L which had estimated flows of 150 gpm and 25 gpm respectively.

Three of the 11 stations (Stations 3D, 3G and 3J) discharged uncontaminated water to Garrison Run. Station 3J, however, contained evidence of minor industrial pollution. Five stations (Stations 3B, 3C, 3E, 3F and 3M) contained evidence of definite industrial and municipal pollution. Stations 3H, 3K and 3L appeared to be the most polluted discharges to the tube. Station 3H contained significant amounts of fecal coliform, BOD and suspended solids. This station appears to be a combined sewer overflow. Station 3K contained an extremely high level of iron and appears to be of industrial origin. Staion 3L contains high levels of fecal coliform, BOD, suspended solids and heavy metals, indicating contamination by industrial and sanitary wastewater.

Overall, the structural condition of the tube is in excellent condition. Sediments and slime growth cover the bottom invert of the tube, but do not markedly affect the flow capacity through the pipe.

The City of Erie is aware that some of the combined sewers will overflow into Garrison Run during periods of peak flow. However, our investigation has verified that combined sewer overflows discharge to the tube in dry weather. Since the City of Erie will probably retain the combined sewer system in this section of the city, the occurrence of the dry weather combined sewer overflows should be investigated and corrected if possible.

It is recommended that a short-range program be adopted and implemented by the City of Erie to improve the quality of dry-weather flow through Garrison Run. First, the industry which appears to be discharging to Garrison Run in the vicinity of 9th and 10th Streets should be investigated and informed of the occurrence. Although the quantity of this industrial discharge is unknown, the high concentration of metals found in the waste is of sufficient quantity to affect water quality in Garrison Run. The industrial discharger is believed to be one of the six mentioned in this report. The industrial waste should be properly rerouted to the municipal sewer system for treatment.

The City of Erie should order Frontier Lumber Company, 762 East 5th Street, to clean out the construction debris, etc. that the company negligently dumped into the 5th and Wayne Streets outfall of Garrison Run. Not only is transmission of the tube flow hindered, but the open channel portion of Garrison Run is unsightly.

The City of Erie should investigate the oily musty smell detected in the sewer connection between 15th and 18th Streets next to Penn Central's Wayne Street Station.

The City of Erie should investigate all of the discharges sampled in this study to further define the characteristics of each discharge. Primary emphasis should be placed on Stations 3H, 3R and 3L. Secondary emphasis should be given to Stations 3B, 3C, 3E, 3F and 3M. Once the sources of contaminated discharges are identified, efforts should be made to eliminate these discharges or at least eliminate the constituents that are detrimental to water quality. A monitoring program should be initiated to check the characteristics of the various discharges and the water quality of Garrison Run. Upstream and downstream stations should be established in Garrison Run.

SECTION IX
PENN CENTRAL SURVEY

Introduction

The Penn Central Wayne Street Station, commonly referred to as the O.D. Yard, is a 60 acre tract owned by Penn Central Railroad. The boundaries to the north and south are 15th and 18th Streets. From each to west, the tract is encompassed by East Avenue and Ash Street.

The yard has been in operation since June, 1918. Over the years numerous buildings have been constructed at the station for yard operation purposes. These buildings include the following:

Machine Shop
Blacksmith shop
Car shop
Car inspection shop
Sand loading tower
Fueling tanks
Motor repair shop
Track repair shop
Water treatment plant

Although not used quite as heavily, the yard is still used to service the fuel yard-type locomotives and for temporary storage of railcars not in transit.

A survey of the Wayne Street Station was performed to determine actual and potential sources of water pollution resulting from surface runoff conditions existing on the railyard property. One aspect of the survey was to determine if Penn Central is responsible for oil contamination via storm water runoff into Garrison Run tube and subsequently into Lake Erie. The oil that has accumulated at the open end of the tube at Fifth Street and Wayne Street may have originated from this source. Garrison Run is located adjacent to the east side of the yard property whereas the old Garrison Run culvert is located below the Wayne Street Station property. The oily, musty smell detected in Garrison Run during the investigation may have eventuated from the station.

A comprehensive survey of the Penn Central yard was performed. Topography, drainage conditions, railyard operations, pertinent runoff characteristics, and right-of-way maps were studied. In addition, storm water runoff samples were collected and analyzed. Oil pollution problems resulting from leakage, spillage and overflow were investigated in the study.

Review of all collected data indicated that runoff from the Penn Central Yard was effecting the water quality in the Garrison Run tube by contributing high concentrations of oil and grease. A waste abatement program was developed to prevent oil from reaching Garrison Run and Lake Erie. Conceptual design and cost estimates for the wastewater abatement system were also developed.

Past Railyard Operations

Originally, the yard was owned and operated by the Pennsylvania Railroad. Since 1968, however, Penn Central Railroad has assumed ownership and operation of the station. For this reason, railyard operations that existed at the O.D. yard 10 to 20 years ago are not definitely known. Most of the pertinent information concerning railyard operations was obtained from a Right-of-Way and Track Valuation Map, connection with NYCRR, Erie, Pennsylvania, drawn by Pennsylvania Railroad engineers. A copy of this map is presented in Figure 15.

As previously stated, the O.D. yard has been in operation since June, 1918. Railyard operations are illustrated in Figure 15 and are listed below:

Facility	Operation
Machine Shop	Engine maintenance
Blacksmith Shop	Track, engine and car repair
Car Shop	Car washing
Car Inspection Shop	Checking point to determine if car needs washing or repair, or the destination of out-going cars
Sand Towers	Loading sand into locomotive hoppers
Fueling Tanks	Three storage tanks for fueling
Water Treatment Plant	Softening water for steam locomotives.
Oil House	Locomotive lubrication

Various other buildings and features exist at the O.D. yard and are shown in Figure 15. These include a tool shop, supply shop, two motor houses, storehouse, bunkhouse, and various office and service buildings. A roundhouse was employed for housing locomotives and for switching them to other tracks. Approximately fifteen miles of track exist at the O.D. yard.

Present Railyard Operations

Penn Central has abandoned almost all railyard operations at the O.D. yard. The yard is still employed for fueling yard-type locomotives, for light locomotive and car servicing, for sand loading, and for temporary storage of railcars. According

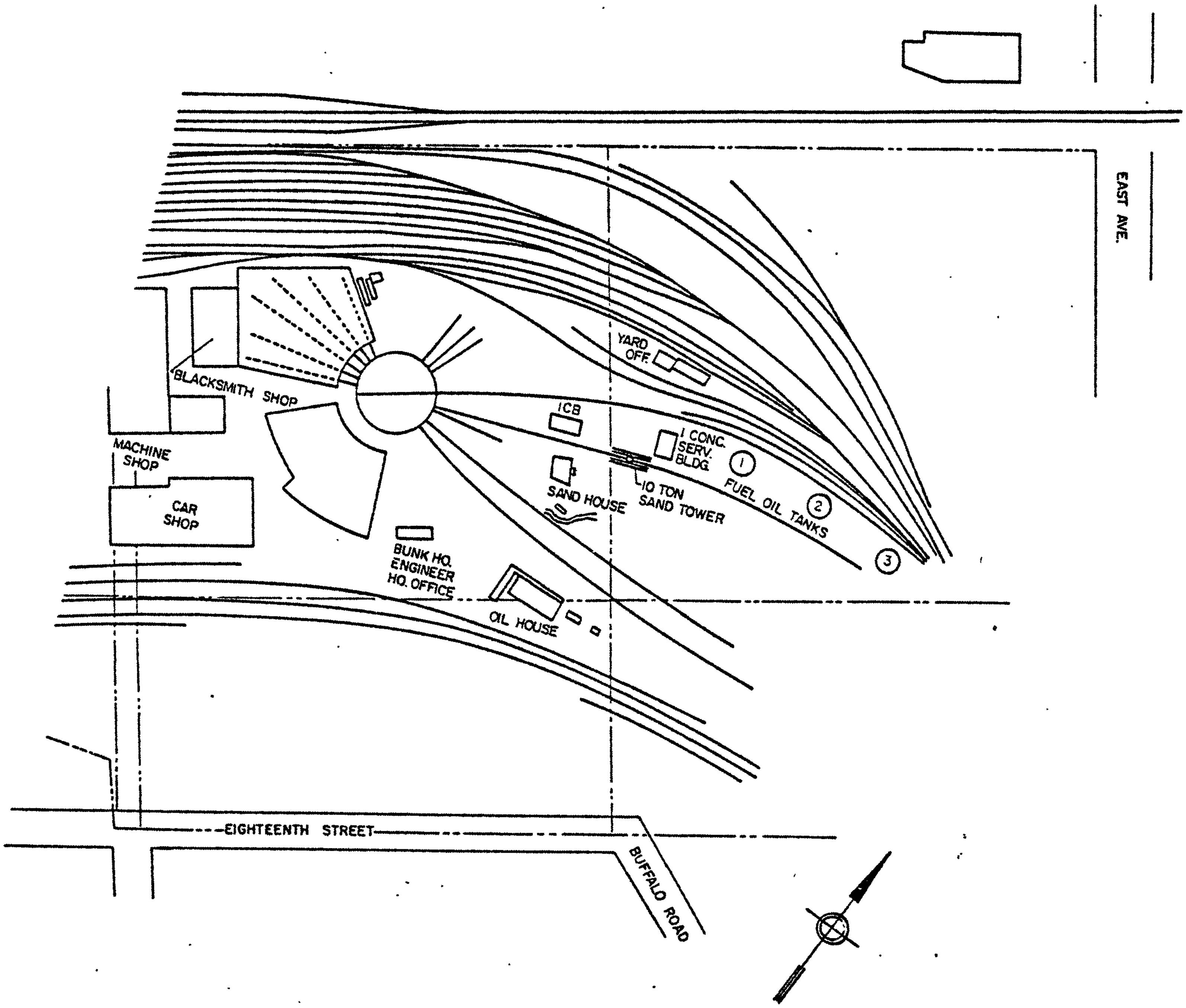


FIGURE 15
PENN CENTRAL PROPERTY MAP

to Penn Central personnel, the yard was used for car washing and cleaning, track repair, and engine maintenance on a regular basis ten years ago. A local firm, Consolidated Grain, was contracted three years ago by Penn Central for car cleaning and washing. However, this practice has been abandoned for economic reasons. Presently, all heavy locomotive and car servicing and repair are conducted at the Collinswood, Ohio Yard Station on a regular basis.

Three above-ground fuel oil storage tanks are located at the yard. The total capacity of these tanks is 150,000 gallons. However, only 25,000 to 50,000 gallons of fuel oil are stored at any given time. A maximum of six (average three to four) yard-type locomotives are fueled every day. As a spill prevention measure, Penn Central personnel only fill the railyard locomotives to about 75 percent capacity. This amounts to about 500 to 700 gallons per fueling or 9,000 gallons of fuel oil per week. Two fuel deliveries are needed weekly to meet this demand.

During the fueling operation, the locomotives are sand loaded from an adjacent tower. Approximately 400 pounds of sand are loaded in the locomotive hopper.

There are two company personnel at the station at all times. They are responsible for guarding the yard property against vandalism and for the yard operations.

Only two buildings at the yard are now used. The workmen use the service building located just west of the fuel tanks for an office. The other building located east of the chemical treatment plant is used for storage. All other buildings and features are now abandoned.

Survey of Penn Central O.D. Yard

A survey of the O.D. Yard was made to determine if oil spillage or leakage from the Station was draining into Garrison Run tube as a portion of storm water runoff. The area of concern was primarily relegated to fuel oil storage, engine maintenance, and the lube oil house since these are the only yard operations that use oil.

The Penn Central property was studied to determine topographic and drainage characteristics. Results of this survey are summarized below:

1. No oil saturation of the ground was evident in the area of the car shop, machine shop, blacksmith shop, lube oil house and engine house.

2. The ground was heavily saturated with oil in the area of the fuel oil storage tanks, sand tower and office buildings.

3. The roundhouse had approximately three inches of rainwater in the basin. The standing water which was red in appearance did not show any presence of oil contamination.

4. Two covered and sealed catch basins were located on the yard property as shown in Figure 16. Oily standing water was present in Catch Basin #1 whereas a relatively clean water was flowing through Catch Basin #2.

5. The area around the sand house was highly eroded. A drainage ditch encompasses the abandoned motor house (see Figure 16) with no existing point of discharge.

6. Although no land level surveying was performed, the terrain was found to slope in a northeast direction. The terrain next to the office (pump-house) slopes toward the roundhouse.

It appears that if an oil spill did occur in the area of concern, some of the oil would be retained by the porous gravel and rock strata underlying the surrounding railtrack. This is evidenced by a thick oil coating found along the ground surface. In addition, some of the oil would collect in the catch basins located west of the fuel tanks and also in the drainage ditch located around the motor house.

Infiltration of the oil through the soil surface could not be estimated. Since the investigation was performed in dry weather, oil simulation runoff evaluations could not be made. In summary, however, it appears that the soil on the yard property is loose and permeable with a high infiltration capacity. Therefore, oil runoff would be limited to a very small area.

It is believed that storm water runoff is saturating the ground surface, picking up oil and soil particles and carrying them through the yard storm water drainage system. The point of collection for discharge into the Garrison Run tube is primarily the old Garrison Run culvert and a storm sewer that runs approximately parallel to the culvert. The storm water-oil mixture drains to the Garrison Run tube at a point designated in Section VIII as Sample Station 3E. This is a 24" concrete connection with a continuous dry weather flow of about 150 gallons per minute. The continuous flow appears to originate from the Garrison Run culvert. Although storm, sanitary or combined sewer maps of the O.D. yard could not be located

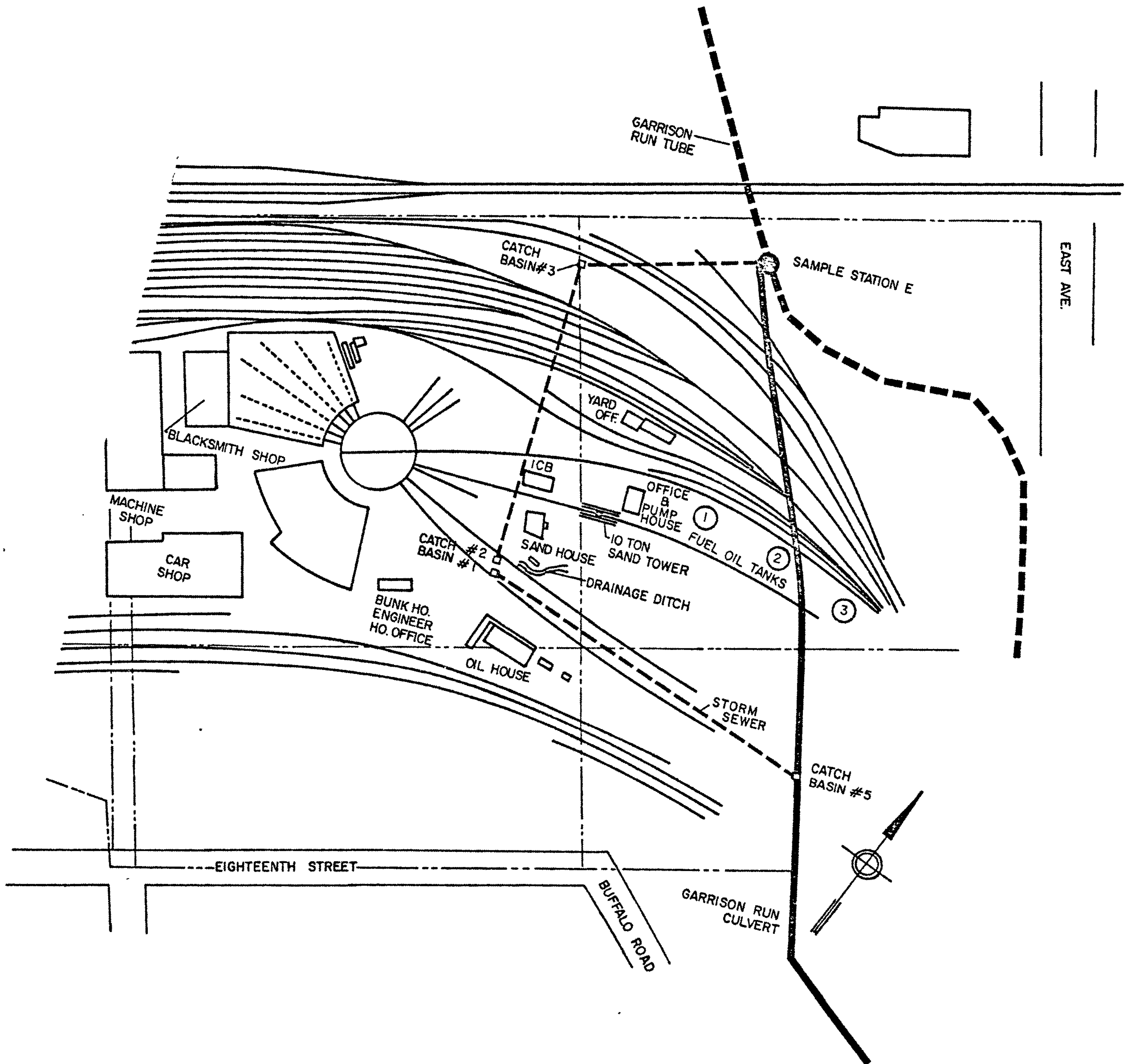


FIGURE 16
PENN CENTRAL DRAINAGE MAP

(according to Penn Central personnel, these maps do not exist), the location of Garrison run tube and culvert on the property has been determined by sanitary sewer maps of Garrison Run. These maps were prepared by the City of Erie Engineering Department, dated October 9, 1970. Based on information obtained from Penn Central personnel, the fuel loading area is encompassed by french drains which discharge storm water to the Garrison Run culvert. All sanitary wastes originating from shop buildings supposedly drained into the Garrison Run culvert when the yard was fully operational. Whether or not this connection to the culvert still exists could not be determined. The location of the Garrison Run tube and culvert and the O.D. yard drainage system is presented in Figure 16. The yard drainage system was estimated by the location of Catch Basins #1, 2, and 3 which appear to be on a straight line and flowing north. These catch basins were full of water, oil and debris. The drainage ditch was also found to contain an oil-water mixture. Wastewater samples were collected from the drainage ditch and from Catch Basins #1 and #2. Results of the analyses performed on these samples are presented in Table 13. The standing water in Catch Basin #1 had extremely high concentrations of suspended solids, oil and grease, and iron. The concentrations of these waste constitutents are summarized below for the three waste sources.

	Suspended Solids (ppm)	Oil & Grease (ppm)	Total Iron (ppm)
Drainage Ditch	780	7,532	8.7
C.B. #1	32	28,380	520
C.B. #2	2,710	41	3.6

Although dye-tracer studies could have better defined the direction of storm water runoff and flow, the location of the catch basins in context with known Sample Station 3E is a relatively accurate measure of drainage flow. Water was flowing from Catch basin #5 in a westerly direction to Catch Basin #1 and #2. From this location water appeared to be flowing in a northerly direction through Catch Basin #3. At this point, the water flows in an easterly direction, combines with flow from the Garrison Run culvert, and discharges directly through a 24" connection into Garrison Run tube.

In summary, it appears that oil saturated ground in the area of the fuel tanks is the source of at least part of the oil contamination found in the Garrison Run tube. Storm water runoff in this area is carrying the oil to either the french drain (exact location unknown) or to Catch Basins #1 or #2. The point of discharge is Sample Station 3E.

TABLE 13

PENN CENTRAL WASTEWATER CHARACTERISTICS DATA

PARAMETER	Drainage Ditch (00)	Catch Basin (01)	Catch Basin (02)
pH, units	7.8	7.2	7.6
Color, units	300	500	25
TOC, mg/l	239,920	-	125
TIC, mg/l	80	-	25
Total Carbon, mg/l	240,000	-	150
Alkalinity as $CaCO_3$, mg/l	192	272	94
Total Solids, mg/l	1,200	14,936	230
Suspended Solids, mg/l	780	2,710	32
Specific Conductance, micromhos 18°C, mg/l	350	500	290
Specific Conductance, micromhos 25°C, mg/l	415	590	340
Oil and Grease, mg/l	7,532	28,380	41
Total Iron, mg/l	8.7	520	3.6
Copper, mg/l	0.05	0.02	0.32
Zinc, mg/l	0.10	0.10	0.10
Chrome, mg/l	0	0	0
Aluminum, mg/l	1.2	13.9	1.1
Lead, mg/l	0.014	1.5	0.034
Mercury, mg/l	0.001	0.0002	0.002
Cadmium, mg/l	0.01	0.01	0.01

Date Sampled: 5/6/74

Oil Spill Prevention Program

In compliance with the Environmental Protection Agency's Oil Spill Prevention Control and Countermeasure Plan (SPCC), all owners or operators of onshore and offshore facilities (non-transportation related) that have discharged or could reasonably be expected to discharge oil in harmful quantities into or upon the navigable waters of the United States must:

1. Prepare an SPCC plan within six months after January 24, 1974.
2. Fully implement the plan as soon as possible.

Penn Central apparently has not complied with this statute by failing to implement the SPCC provisions as outlined in Federal Register Volume 38, No. 237. The O.D. yard facility is applicable to the provisions outlined since it is "a facility which has an aggregate storage of more than 1320 gallons of oil" (CFR, Volume 38). Thus, Penn Central appears to be liable for a civil penalty for each day that the violation continues.

In general, the purpose of this survey was to ascertain whether contaminated wastewaters were emanating from the Penn Central yards and to develop a conceptual solution if such a problem exists. Specific objectives included investigation of potential oil spill areas at the yard and spill prevention and containment methods needed at the yard. The potential oil spill area has been defined. The spill prevention and containment measures to be discussed strive to meet one criteria: elimination of any oil discharge to the Garrison Run tube.

About 25,000 to 50,000 gallons of fuel oil are stored in three above-ground 50,000 gallon steel tanks for fueling locomotives. Since 9,000 gallons are consumed weekly, it is necessary to have at least two fuel deliveries weekly. The fuel reserve (16,000 to 41,000 gallons) is apparently required to insure availability of oil during fuel shortages or adverse weather. Other bulk storage of oil is minimal and is contained in the pump house (or office). This is used for minor servicing.

Based on the information obtained, including past pollution incidents, the largest spill which potentially might occur would be about 50,000 gallons. This includes a fuel delivery as part of the spill.

The three storage tanks are properly diked individually by a four foot high earthen wall. If the quantity of oil stored is evenly distributed among the three tanks, any oil spill occurring on the inside of the wall will be properly retained. In addition, the tanks contain vent pipes and shutoff pressure type valves as added safety measures.

It appears that if an oil spill did occur at the O.D. yard, it would be at the point of fuel transfer for both unloading and loading operations. Although all transfer pipes are equipped with locked check valves, an oil leak caused by pipe abrasion or break would not be contained in the immediate area. Although the above-ground strata is very porous, some oil would probably escape to Catch Basins #1 and #2 or to the french drainage system. Undoubtedly, much of this oil would drain to Garrison Run. In addition, all transfer pipelines in this area are above ground which increases the probability of a spill occurrence in this area. In the area of the pumphouse, the ground is heavily saturated with oil. Although no spill events have been reported, this area is indicative of many minor spills.

Recommended oil spill prevention and containment measures in compliance with SPCC regulations and guidelines for the Penn Central O.D. yard are summarized below:

1. Provide an asphalt lined drainage ditch around the pumphouse and fuel tanks as shown in Figure 17. Ground storm water seepage should be minimized by providing an impervious base on the ground surface.

2. Provide an oil containment separation basin to collect the gravity flow of fluid from the ditch. (See Figure 16.) An effluent pipe will be required to discharge clean water to the Garrison Run culvert or tube.

3. Use Fuel Tanks #1 and #2 for fuel storage and Fuel Tank #3 as a standby for waste oil storage. Any oil that accumulates in the separation basin should be manually pumped to the Fuel Tank #3.

4. Implement a cleanup program to clean out Catch Basins #1 and #2 and level the existing drainage ditch next to the motor house.

By implementing the above program, the existing drainage system at the yard, including the storm sewer and the Garrison Run culvert, can be maintained to carry only storm water flow. The collection system described will segregate any oil from storm water runoff.

The oil containment-separation basin should be a below-grade basin properly baffled to deflect and retain any collected oil. Rainfall intensity calculations for the enclosed surface area to be drained indicate that the basin should have a capacity of about 1,500 gallons.

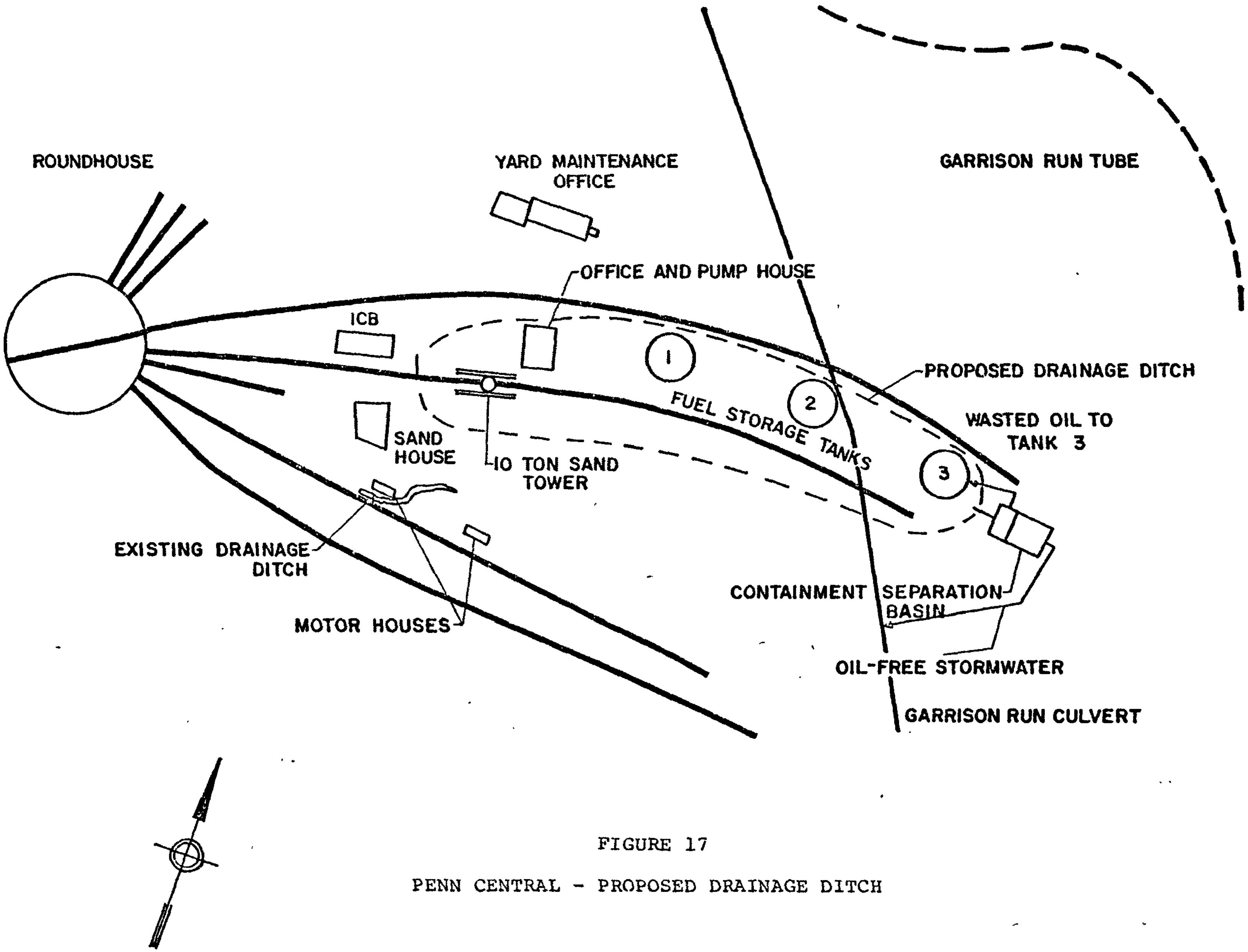


FIGURE 17

PENN CENTRAL - PROPOSED DRAINAGE DITCH

A portable floating oil skimmer should be installed to collect floating oil in the containment chamber and transfer the waste oil to Tank #3. An inverted siphon is recommended to discharge storm water in the basin to Garrison Run. A schematic diagram of the basin is presented in Figure 18. The design is such that the depth of liquid in this basin must be near capacity before storm water discharge will occur. The suction end of the siphon should be placed near the bottom of the basin to insure that only oil-fuel water will be discharged. A check valve (with bleeder) should be installed on the siphon so that visual inspection of discharge can be made. If oil is evident in the discharge siphon, the valve would be closed and the basin's contents would be pumped to the waste storage facility.

If Penn Central implements the recommended spill containment measures, the major oil contamination in the Garrison Run tube should be eliminated.

No recommendations were made for the existing french drains around the fuel tanks. Since Penn Central does not know the location of these drains, emphasis has been placed on encouraging storm water runoff rather than infiltration. Also, the existing french drains can be left in place if the fuel oil pads are covered with an asphalt base.

In order to implement a successful SPCC plan, the following program should be initiated by Penn Central:

1. Establish an SPCC program coordinator to administer all aspects of the program.

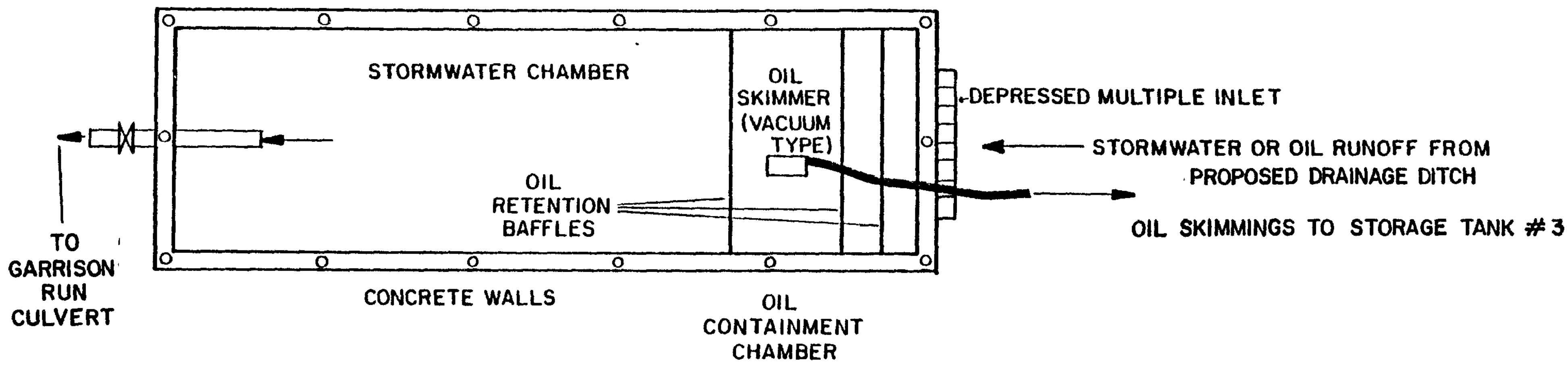
2. Train yard personnel in spill prevention technology.

3. Initiate oil spill contingency procedures in the event of a spill.

4. Inspect on a routine basis all oil tanks, transfer pipe, valves, pumps, and the basin for evidence of damage, wear, or oil leakage.

Cost of Technology

Since two Penn Central personnel are located at the yard at all times, no additional operating costs are foreseen in implementing the SPCC plan. The total investment cost of the SPCC plan to be fully implemented is estimated to be $70,000 in 1975 dollars.



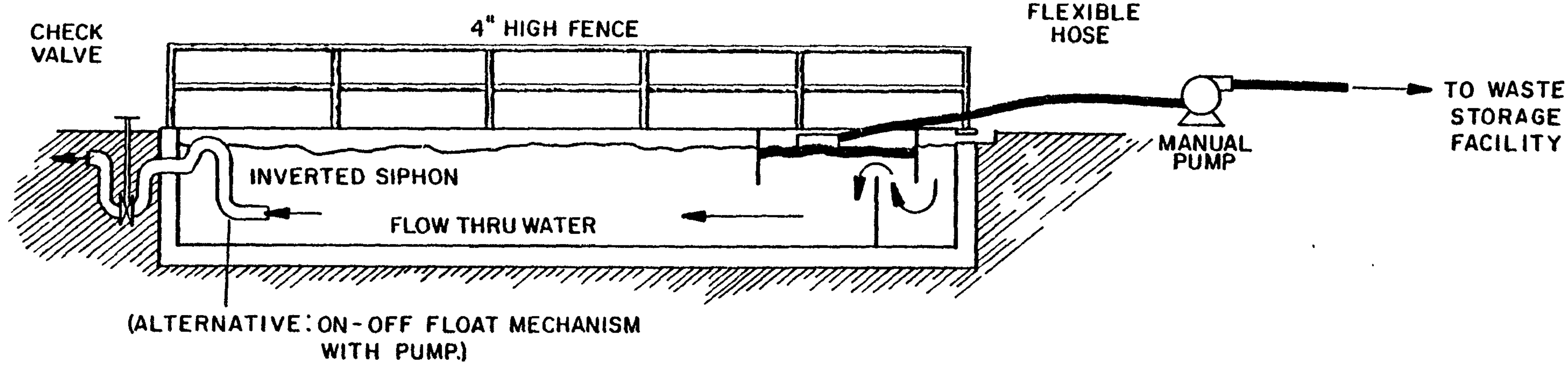


FIGURE 18

PENN CENTRAL OIL CONTAMINATION-SEPARATION BASIN

SECTION X
ACKNOWLEDGEMENTS

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SECTION XI
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SECTION XII

APPENDIX A

CHEMICAL AND PHYSICAL DATA

APPENDIX A-1

CHEMICAL AND PHYSICAL DATA FOR LAKE STATIONS

CONSTITUENT	STATION	SAMPLING DATE					
		9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Total Solids mg/l							
	2	218	215	193	205	233	172
	4	219	215	205	-	240	198
	4A	-	-	132	-	-	-
	5	215	210	200	200	230	196
	6	207	228	193	211	236	266
	6A	-	-	265	-	379	218
	7	189	208	194	193	204	210
	8	195	199	187	197	217	192
	9	189	205	187	-	207	202
	10	232	213	229	-	298	214
	11	-	-		207	-	-
	12	-	-	-	-	-	214
Suspended Solids mg/l							
	2	7	4	4	2	3	8
	4	6	4	4	-	6	8
	4A	-		18	-	-	
	5	7	5	5	6	6	8
	6	4	8	9	12	8	6
	6A	-	-	28	-	108	26
	7	5	7	10	8	6	6
	8	7	6	10	8	4	4
	9	4	5	10	-	5	6
	10	10	3	14	-	17	12
	11	-	-	-	3	-	-
	12	-	-	-	-	-	20

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Nitrate as N mg/l	2	0.054	0.040	0.213	0.213	0.42	0.90
	4	0.041	0.023	0.191	-	0.67	1.60
	4A	-	-	0.470	-	-	-
	5	0.010	0.010	0.158	0.204	0.75	0.90
	6	0.039	0.016	0.194	0.193	1.18	1.60
	6A	-	-	0.223	-	1.21	0.40
	7	0.026	0.010	0.190	0.179	0.16	1.30
	8	0.042	0.011	0.190	0.154	1.71	1.30
	9	0.026	0.023	0.183	-	1.06	1.10
	10	0.029	0.010	0.158	-	0.93	1.30
	11	-	-	-	0.199	-	-
	12	-	-	-	-	-	1.80
Ammonia as N mg/l	2	0.285	0.035	0.145	0.165	0.320	0.060
	4	0.080	0.030	0.148	-	0.310	0.060
	4A	-	-	2.600	-	-	-
	5	0.150	0.010	0.161	0.150	0.220	0.060
	6	0.035	0.023	0.060	0.070	0.220	0.100
	6A	-	-	0.113	-	0.260	0.100
	7	0.020	0.010	0.050	0.065	0.270	0.060
	8	0.050	0.010	0.063	0.060	0.300	0.060
	9	0.030	0.130	0.060	-	0.510	0.060
	10	0.048	0.010	0.010	-	0.280	0.060
	11	-	-	-	0.150	-	0.400
Total Kjeldahl Nitrogen mg/l	2	0.29	0.06	-	0.52	2.00	0.26
	4	0.14	0.11	-		0.56	0.26
	4A	-	-	-	-	-	-
	5	0.14	0.06	-	2.40	0.59	0.36
	6	0.10	0.06	-	0.42	0.53	0.30
	6A	-	-	-	-	0.78	0.50
	7	0.10	0.05	-	0.28	0.57	0.46
	8	0.15	0.04	-	0.23	0.72	0.46
	9	0.11	0.16	-		0.84	0.26
	10	0.11	0.05	-		1.47	0.66
	11	-	-	-	0.48	-	-
	12	-	-	-	-	-	0.80

APPENDIX A-1 *(cont.)*

CONSTITUENT	STATION	SAMPLING DATE					
Organic Nitrogen mg/l		9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
	2	0.01	0.03	-	0.36	1.68	0.20
	4	0.06	0.08	-	-	0.25	0.20
	4A	-	-	-	-	-	-
	5	0.13	0.06	-	2.30	0.37	0.30
	6	0.07	0.04	-	0.35	0.31	0.20
	6A	-	-	-	-	0.52	0.40
	7	0.08	0.05	-	0.22	0.30	0.40
	8	0.10	0.04	-	0.17	0.42	0.40
	9	0.08	0.03	-	-	0.33	0.20
	10	0.06	0.05	-	-	1.19	0.60
	11	-	-	-	0.33	-	-
	12	-	-	-	-	-	0.40
Total Phosphorus							
	2	0.05	0.06	0.05	0.11	0.02	0.17
	4	0.07	0.08	0.05	-	0.02	0.13
	4A	-	-	1.77	-	-	-
	5	0.05	0.04	0.05	0.19	0.02	0.07
	6	0.04	0.05	0.05	0.09	0.02	0.17
	6A	-	-	0.07	-	0.03	0.13
	7	0.03	0.04	0.05	0.14	0.02	0.23
	8	0.02	0.03	0.06	0.11	0.03	0.17
	9	0.02	0.14	0.06	-	0.03	0.20
	10	0.04	0.02	0.06	-	0.02	0.20
	11	-	-	-	0.11	-	-
	12	-	-	-	-	-	0.13
Total Dissolved Phosphorus as P mg/l	2	0.040	-	0.024	0.074	0.012	0
	4	0.055	-	0.024	-	0.012	0.067
	4A	-	-	0.650	-	-	-
	5	0.027	-	0.026	0.180	0.005	0
	6	0.032	-	0.024	0.080	0.008	0
	6A	-	-	0.028	-	0.023	0
	7	0.025	-	0.020	0.042	0.023	0
	8	0.013	-	0.026	0.114	0.009	0
	9	0.013	-	0.024	-	0.028	0
	10	0.030	-	0.024	-	0.018	0
	11	-	-		0.108	-	0
	12	-	-	-	-	-	0

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	SAMPLING DATE					
		9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Alkalinity	2	92	95	94	92	92	108
	4	93	93	94	-	97	104
	4A	-	-	120	-	-	-
	5	92	93	93	93	91	106
	6	92	93	90	92	93	222
	6A	-	-	91	-	94	194
	7	91	89	87	90	95	188
	8	90	91	87	89	92	182
	9	90	90	87	-	92	188
	10	98	91	95	-	98	186
	11	-	-	-	92	-	-
	12	-	-	-	-	-	174
pH	2	7.8	8.0	7.5	7.9	7.4	8.0
	4	7.9	8.1	7.8	-	7.2	7.4
	4A	-	-	6.9	-	-	-
	5	7.9	8.1	7.9	7.8	7.3	8.0
	6	7.9	7.9	7.8	7.7	7.2	7.3
	6A	-	-	7.6	-	6.9	7.3
	7	7.9	8.0	7.9	7.8	7.1	7.5
	8	7.9	8.0	7.9	8.0	7.2	7.6
	9	7.9	8.0	7.6	-	7.1	7.6
	10	7.8	7.9	7.7	-	7.1	7.6
	11	-	-	-	7.9	-	-
	12	-	-	-	-	-	7.4
Biochemical Oxygen Demand mg/l	2	5	10	6	4	2	-
	4	6	12	10	-	1	-
	4A	-	-	70	-		-
	5	7	11	6	4	5	-
	6	6	16	10	7	36	2
	6A	-	-	34	-	-	24
	7	6	17	6	5	2	0
	8	6	21	6	4	9	5
	9	6	15	6	-	4	2
	10	11	13	9	-	14	5
	11	-	-	-	4		
	12	-	-	-	-	-	2

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Total Organic Carbon mg/l							
	2	-	11	9	7	9	-
	4	-	9	13	-	9	-
	4A	-	-	33	-	-	-
	5	-	11	6	8	10	-
	6	-	20	12	14	-	-
	6A	-		24	-	-	-
	7	-	9	9	11	7	-
	8	-	10	11	6	7	-
	9	-	9	12	-	9	-
	10	-	15	15	-	21	-
	11	-	-	-	7	-	-
	12	-	-	-	-	-	-
Dissolved Orthophosphate mg/l	2	0.015	<0.01	0.102	0.014	0.006	0.00
	4	0.02	<0.01	0.014	-	0.002	0.06
	4A	-	-	0.477	-	-	-
	5	0.01	<0.01	0.014	0.028	<0.001	0.00
	6	<0.01	<0.01	0.010	0.010	<0.001	0.00
	6A	-	-	<0.010	-	0.001	0.00
	7	<0.01	<0.01	0.010	0.018	0.012	0.00
	8	<0.01	<0.01	0.014	0.014	0.015	0.00
	9	<0.01	0.02	0.014	-	0.028	0.00
	10	<0.01	<0.01	<0.010	-	0.018	0.00
	11	-	-	-	0.018	-	-
	12	-	-	-	-	-	0.00
Nitrite as N mg/l							
	2	0.016	0.019	0.017	0.012	0.180	-
	4	0.014	0.022	0.019	-	0.135	-
	4A	-	-	-	-	-	-
	5	0.005	0.010	0.042	0.011	0.180	-
	6	0.016	0.024	0.026	0.007	0.190	-
	6A	-	-	0.032	-	0.205	-
	7	0.014	0.018	0.020	0.006	0.327	-
	8	0.013	0.019	0.020	0.006	0.200	-
	9	0.013	0.032	0.017	-	0.148	-
	10	0.006	0.028	0.032	-	0.239	-
	11	-	-	-	0.011	-	-
	12	-	-	-	-	-	-

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
		SAMPLING DATE					
Color Units							
	2	4	-	-	5	3	10
	4	7	-	-	-	<1	15
	4A	-	-	-	-	-	-
	5	6	-	-	5	5	15
	6	10	-	-	5	6	15
	6A	-	-	-	-	12	65
	7	3	-	-	<5	4	15
	8	2	-	-	<5	3	10
	9	4	-	-	-	4	10
	10	35	-	-	-	30	40
	11	-	-	-	5	-	-
	12	-	-	-	-	-	25
Specific Conductivity mohms/cm	2	-	320	325	345	358	385
	4	-	380	330	-	360	385
	4A	-	-	320	-	-	-
	5	-	370	320	335	334	415
	6	-	400	304	320	350	355
	6A	-	-	365	-	435	440
	7	-	360	280	300	321	355
	8	-	355	290	300	333	330
	9	-	360	281	-	332	340
	10	-	380	345	-	425	415
	11	-	-	-	340	-	-
	12	-	-	-	-	-	385
Iron µg/l							
	2	480	734	470	400	158	100
	4	464	424	412	-	176	100
	4A	-	-	740	-	-	-
	5	200	198	398	260	230	200
	6	232	336	480	820	384	200
	6A	-	-	624	-	650	400
	7	172	376	546	460	250	100
	8	132	344	518	420	340	50
	9	244	188	614	-	270	100
	10	156	120	512	-	580	300
	11	-	-	-	300	-	-
	12	-	-	-	-	-	700

CONSTITUENT	STATION	9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Copper µg/l							
	2	1.0	8.6	2.2	15.2	4	10
	4	13.4	3.2	1.0	-	4	0
	4A	-	-	18.8	-	-	-
	5	2.0	1.6	1.0	6.6	4	0
	6	3.4	4.4	1.0	6.4	4	0
	6A	-	-	6.6	-	10	0
	7	<1.0	2.2	1.8	5.6	18	0
	8	<1.0	9.0	2.2	5.4	6	0
	9	<1.0	<1.0	1.0	-	8	0
	10	1.6	<1.0	8.8	-	8	0
	11	-	-	-	7.0	-	-
	12	-	-	-	-	-	0
Lead µg/l							
	2	6	8	10	10	13	<10
	4	8	6	2	-	12	<10
	4A	-	-	20	-	-	-
	5	6	<2	2	22	15	<10
	6	8	2	<2	10	14	<10
	6A	-	-	4	-	18	<10
	7	6	2	<2	16	12	<10
	8	4	10	2	12	30	<10
	9	8	2	2	-	21	<10
	10	4	<2	8	-	18	<10
	11	-	-	-	16	-	-
	12	-	-	-	-	-	<10
Zinc µg/l							
	2	53	28	26	<2	13	0
	4	6	15	65	-	4	0
	4A	-	-	88	-	-	-
	5	20	8	<2	4	5	0
	6	6	10	<2	4	7	0
	6A	-	-	264	-	20	0
	7	5	10	52	2	8	0
	8	40	23	<2	2	10	0
	9	3	2	<2	-	12	0
	10	8	6	39	-	17	0
	11	-	-	-	4	-	-
	12	-	-	-	-	-	0

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
Cadmium/µg/l							
	2	2.6	2.2	3.4	3.2	0.009	<10
	4	2.7	3.0	2.9	-	0.009	<10
	4A	-	-	12.8	-	-	-
	5	1.0	13.1	1.2	2.4	0.012	<10
	6	1.7	2.2	1.0	3.4	0.013	<10
	6A	-	-	1.0	-	0.013	<10
	7	1.3	2.7	1.4	2.8	0.015	<10
	8	1.6	2.6	1.0	3.0	0.010	<10
	9	1.2	1.5	<1.0	-	0.015	<10
	10	1.2	1.3	1.8	-	0.015	<10
	11	-	-	-	3.2	-	-
	12	-	-	-		-	<10
Chromium µg/l							
	2	54	162	69	4	3	0
	4	27	74	51	-	4	0
	4A	-	-	32	-	-	-
	5	41	17	17	20	3	0
	6	6	40	12	10	2	0
	6A	-	-	23	-	10	0
	7	5	24	12	8	4	0
	8	5	56	< 1	6	3	0
	9	5	33	54	-	6	0
	10	12	32	< 1	-	6	0
	11	-	-	-	<4	-	-
	12	-	-	-	-	-	0
Aluminum µg/l							
	2	384	223	407	250	120	300
	4	318	251	231	-	180	300
	4A	-	-	233	-	-	-
	5	120	114	291	220	200	200
	6	235	314	577	640	330	240
	6A	-	-	1376	-	1850	700
	7	153	309	488	490	240	150
	8	269	303	645	440	350	170
	9	197	196	477	-	260	50
	10	171	163	919	-	930	160
	11	-	-	-	230	-	-
	12	-	-	-	-	-	500

APPENDIX A-1 (cont.)

CONSTITUENT	STATION	SAMPLING DATE					
Mercury μg/l		9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
	2	0.82	7.22	<0.10	0.7	8.3	4.0
	4	0.40	2.11	<0.10	-	8.3	4.7
	4A	-	-	0.40	-	-	-
	5	1.24	4.82	<0.10	1.0	3.6	6.7
	6	0.82	5.29	<0.10	0.6	10.4	5.4
	6A	-	-	<0.10	-	-	5.3
	7	<0.1	2.55	<0.10	1.0	7.4	1.5
	8	<0.1	3.44	0.82	<0.1	19.0	1.3
	9	1.24	2.99	<0.1	-	3.8	1.2
	10	0.82	4.35	<0.1	-	8.9	3.3
	11	-	-	-	<0.1	-	-
	12	-	-	-	-	-	2.0

APPENDIX A-2

CHEMICAL AND PHYSICAL PARAMETERS FOR

STREAM STATIONS 1 AND 3

CONSTITUENT	STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-28-73	5-8/9-74	5-21-74	6-4-74
Total Solids mg/l	1	262	385	317	357	400	348	-
	3	304	447	427	375	223	389	-
Suspended Solids mg/l	1	12.4	2.0	11.4	9.6	170	1	-
	3	15.2	4.2	67.7	45.5	44	28	-
Nitrate as N mg/l	1	1.200	0.204	0.460	0.608	0.894	0.792	-
	3	0.253	0.180	0.595	0.964	1.074	0.010	5.5
Nitrite as N mg/l	1	0.200	0.026	0.150	0.012	0.041	0.36	-
	3	0.062	0.360	0.185	0.036	0.026	1.14	-
Ammonia as N mg/l	1	5.88	0.10	0.13	0.23	0.23	2.50	-
	3	0.14	8.40	3.52	1.53	0.41	3.20	2.00
Total Kjeldahl Nitrogen mg/l	1	5.80	0.11	-	0.41	-	2.51	-
	3	0.43	9.90	-	0.49	-	6.30	3.00
Organic Nitrogen mg/l	1	0.01	0.01	-	0.18	-	0.01	-
	3	0.29	1.50	-	0.36	-	3.10	1.00
Total Phosphorus mg/l	1	0.063	0.07	0.23	0.14	-	0.03	-
	3	0.462	2.30	1.40	1.68	0.11	1.13	0.73

APPENDIX A-2 (cont.)

CONSTITUENT	STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-28-73	5-8/9-74	5-21-74	6-4-74
Total Dissolved Phosphorus	1	0.053	-	0.167	0.120	0.032	0.030	-
	3	0.195	-	1.180	1.300	0.008	0.744	0.333
Dissolved Ortho-phosphate mg/l	1	0.025	0.042	0.058	0.010	0.016	0.030	-
	3	0.145	1.060	0.110	1.150	0.008	0.616	0.26
Alkality mg/l	1	93	116	128	116	99	133	-
	3	113	161	136	102	63	134	-
Biochemical Oxygen Demand mg/l	1	19	6	7	6	14	7	4
	3	33	101	120	87	9	59	-
pH	1	7.2	7.9	7.8	7.9	7.2	7.6	-
	3	7.3	7.2	6.9	6.7	7.1	6.9	-
Specific Conductance mohm/cm	1	-	480	415	525	380	525	-
	3	-	690	512	500	301	574	945
Color Units	1	10	-	-	5	16	4	-
	3	4	-	-	5	20	7	35
Iron µg/l	1	1210	622	1012	1280	12,470	580	-
	3	566	1890	786	1880	4340	832	8400
Copper µg/l	1	17	9	7	10	66	28	-
	3	13	142	138	159	22	58	10
Lead µg/l	1	92	22	18	24	286	22	-
	3	28	32	20	72	82	31	17

APPENDIX A-2 (cont.)

CONSTITUENT	STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-28-73	5-8/9-74	5-21-74	6-4-74
Zinc µg/l								
	1	53	25	27	6	192	27	-
	3	51	348	324	52	82	146	100
Cadmium µg/l								
	1	2.3	2.0	2.8	4.4	3.8	0.02	-
	3	3.1	46.0	46.0	53.4	2.4	0.12	<10
Chromium µg/l								
	1	54	14	66	< 4	14	7	-
	3	46	442	64	88	6	31	0
Aluminum µg/l								
	1	714	361	477	530	3820	200	-
	3	417	419	506	660	1800	300	180
Mercury µg/l								
	1	114.0	4.4	0.4	1.0	1.9	-	-
	3	2.1	2.6	<0.1	0.8	4.1	-	<0.2

APPENDIX A-3

CHEMICAL AND PHYSICAL DATA FOR

CASCADE CREEK

CONSTITUENT	STATION	SAMPLING DATE		
		12-28-73	5-8/9-74	6-4-74
Total Solids mg/l				
	1	357	400	-
	1A	425	320	358
	1B	369	339	198
	1C	335	304	282
	1D	395	372	368
	1E	-	297	302
	1F	-	399	370
	2	-	270	-
	2A	-	195	-
Suspended Solids mg/l				
	1	10	170	-
	1A	6	162	6
	1B	6	132	6
	1C	8	142	10
	1D	4	117	8
	1E	-	152	10
	1F	-	72	12
	2	-	36	-
	2A	-	12	-
Nitrate as N mg/l	1	0.608	0.894	-
	1A	0.695	0.856	0.9
	1B	1.080	1.010	1.3
	1C	0.458	0.768	1.6
	1D	1.020	1.092	2.5
	1E	-	0.796	1.8
	1F	-	1.247	2.0
	2	-	0.948	-
	2A	-	0.357	-
Nitrite as N mg/l				
	1	0.012	0.041	-
	1A	0.005	0.063	-
	1B	0.002	0.020	-
	1C	0.012	0.042	-
	1D	0.008	0.027	-
	1E	-	0.040	-
	1F	-	0.016	-
	2	-	0.031	-
	2A	-	0.006	-

APPENDIX A-3 (cont.)

CONSTITUENT	STATION	SAMPLING DATE 12-28-73	5-8/9-74	6-4-74
Ammonia as N mg/l				
	1	0.230	0.23	-
	1A	0.045	0.26	0.06
	1B	0.045	0.23	0.10
	1C	0.090	0.21	0.06
	1D	0.560	0.42	0.10
	1E	-	0.21	0.40
	1F	-	0.11	0.20
	2	-	0.94	-
	2A	-	0.07	-
Total Kjeldahl Nitrogen mg/l	1	0.41	-	-
	1A	0.30	-	1.60
	1B	0.30	-	0.40
	1C	0.31	-	0.26
	1D	0.53	-	0.20
	1E	-	-	0.50
	1F	-	-	0.30
	2	-	-	-
	2A	-	-	-
Organic Nitrogen mg/l				
	1	0.18	-	-
	1A	0.26	-	0.1
	1B	0.26	-	0.3
	1C	0.22	-	0.2
	1D	-	-	0.1
	1E	-	-	0.1
	1F	-	-	0.1
	2	-	-	-
	2A	-	-	-
Total Phosphorus mg/l				
	1	0.136	0.295	-
	1A	0.058	0.246	0.167
	1B	0.058	0.212	0.167
	1C	0.068	0.241	0.667
	1D	0.068	0.112	0.167
	1E	-	0.144	0.167
	1F	-	0.048	0.133
	2	-	0.660	-
	2A	-	0.011	-

APPENDIX A-3 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
Phosphorus mg/l		12-28-73	5-8/9-74	6-4-74
	1	0.120	0.032	-
	1A	0.022	1.300	0.167
	1B	0.032	0.097	0.067
	1C	0.042	0.042	0.467
	1D	0.048	0.005	0.067
	1E	-	0.070	0.067
	1F	-	0.005	0.067
	2	-	0.485	-
	2A	-	0.008	-
Dissolved Orthophosphate mg/l	1	0.01	-	-
	1A	<0.01	0.057	-
	1B	0.01	0.097	-
	1C	0.01	-	-
	1D	0.01	-	-
	1E	-	-	-
	1F	-	-	-
	2	-	-	-
	2A	-	-	-
Alkalinity	1	116	99	-
	1A	107	61	172
	1B	117	80	96
	1C	107	69	126
	1D	140	94	154
	1E	-	64	134
	1F	-	106	140
	2	-	95	-
	2A	-	64	-
Biochemical Oxygen Demand mg/l	1	6	14	4
	1A	4	22	0
	1B	5	7	0
	1C	5	13	4
	1D	-	8	4
	1E	-	15	0
	1F	-	3	0
	2	-	106	-
	2A	-	15	-

APPENDIX A-3 (cont.)

CONSTITUENT	STATION	SAMPLING DATE 12-28-73	5-8/9-74	6-4-74
pH	1	7.9	7.2	-
	1A	7.9	6.5	7.8
	1B	7.8	7.1	7.9
	1C	7.9	6.9	7.8
	1D	7.8	7.3	8.2
	1E	-	6.9	8.1
	1F	-	7.6	8.0
	2	-	6.9	-
	2A	-	7.9	-
Specific Conductance mohm/cm	1	525	380	-
	1A	640	250	650
	1B	550	350	355
	1C	500	255	500
	1D	600	422	650
	1E	-	245	500
	1F	-	510	590
	2	-	427	-
	2A	-	311	-
Color Units	1	5	16	-
	1A	5	30	10
	1B	5	7	8
	1C	5	20	15
	1D	5	15	15
	1E	-	17	10
	1F	-	3	20
	2	-	14	-
	2A	-	10	-
Iron µg/l	1	1280	12,470	-
	1A	1640	9400	300
	1B	760	7600	500
	1C	1580	8990	800
	1D	1420	6700	700
	1E	-	8650	700
	1F	-	4160	1200
	2	-	1230	-
	2A	-	1010	-

APPENDIX A-3 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
		12-28-73	5-8/9-74	6-4-74
Copper µg/l				
	1	10.2	66	-
	1A	7.4	52	10
	1B	8.0	88	0
	1C	11.6	56	0
	1D	11.0	32	0
	1E	-	54	20
	1F	-	24	0
	2	-	26	-
	2A	-	8	-
Lead µg/l				
	1	24	286	-
	1A	20	554	<10
	1B	18	196	<10
	1C	12	368	<10
	1D	14	186	<10
	1E	-	376	<10
	1F	-	92	<10
	2	-	46	-
	2A	-	14	-
Zinc µg/l				
	1	6	192	-
	1A	4	234	0
	1B	4	192	0
	1C	8	192	0
	1D	6	124	0
	1E	-	188	0
	1F	-	56	0
	2	-	78	-
	2A	-	38	-
Cadmium µg/l				
	1	4.4	3.8	-
	1A	4.2	2.8	<10
	1B	5.0	3.2	<10
	1C	2.6	3.2	<10
	1D	4.4	3.0	<10
	1E	-	2.6	<10
	1F	-	4.4	<10
	2	-	7.0	-
	2A	-	1.2	-

APPENDIX A-3 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
		12-28-73	5-8/9-73	6-4-74
Chromium µg/l				
	1	<4	14	-
	1A	4	8	0
	1B	6	6	0
	1C	6	8	0
	1D	4	6	0
	1E	-	10	0
	1F	-	2	0
	2	-	6	-
	2A	-	<2	-
Aluminum µg/l				
	1	530	3820	-
	1A	570	4800	70
	1B	490	3640	300
	1C	530	4500	400
	1D	700	2340	180
	1E	-	4340	300
	1F	-	2540	300
	2	-	-	-
	2A	-	-	-
Mercury µg/l				
	1	1.0	1.9	-
	1A	2.0	11.7	7.0
	1B	1.0	6.1	12.0
	1C	1.5	2.9	17.0
	1D	2.1	2.3	11.0
	1E	-	2.7	12.0
	1F	-	2.9	9.0
	2	-	-	-
	2A	-	-	-

APPENDIX A-4

CHEMICAL AND PHYSICAL DATA FOR GARRISON RUN

CONSTITUENT	STATION	SAMPLING DATE May 9	May 21	June 4
Total Solids mg/l				
	3	223	389	-
	3A	482	391	-
	3B	-	520	454
	3C	-	296	-
	3D	-	249	170
	3E	-	365	318
	3F	-	484	536
	3G	-	1075	926
	3H	-	531	-
	3I	-	553	448
	3J	-	-	298
	3K	-	-	650
Suspended Solids mg/l				
	3	44	28	-
	3A	232	48	-
	3B	-	5	8
	3C	-	4	-
	3D	-	2	4
	3E	-	4	6
	3F	-	11	10
	3G	-	6	10
	3H	-	14	-
	3I	-	10	10
	3J	-	-	14
	3K	-	-	216
Nitrate mg/l	3	1.074	0.010	5.5
	3A	0.994	0.955	3.8
	3B	-	1.733	2.5
	3C	-	0.874	0.4
	3D	-	0.646	1.3
	3E	-	1.258	2.9
	3F	-	0.922	4.3
	3G	-	0.107	2.5
	3H	-	0.010	-
	3I	-	0.978	0.2
	3J	-	-	1.6
	3K	-	-	0.4

CONSTITUENT	STATION	SAMPLING DATE		
		May 9	May 21	June 4
Nitrite mg/l				
	3	0.026	1.140	-
	3A	0.039	0.485	-
	3B	-	0.095	-
	3C	-	0.124	-
	3D	-	0.110	-
	3E	-	0.220	-
	3F	-	0.758	-
	3G	-	0.795	-
	3H	-	0.671	-
	3I	-	0.352	-
	3J	-	-	-
	3K	-	-	-
Ammonia mg/l				
	3	0.410	3.20	2.00
	3A	0.165	0.54	0.10
	3B	-	0.31	0.06
	3C	-	0.31	0.10
	3D	-	0.29	0.20
	3E	-	0.50	0.20
	3F	-	0.33	0.10
	3G	-	0.50	0.20
	3H	-	0.65	-
	3I	-	0.62	0.06
	3J	-	-	0.10
	3K	-	-	0.10
Total Kjeldahl Nitrogen mg/l	3	-	6.30	3.00
	3A	-	0.57	0.50
	3B	-	0.45	0.16
	3C	-	0.44	0.50
	3D	-	0.86	0.30
	3E	-	1.39	0.40
	3F	-	0.83	0.30
	3G	-	1.96	0.50
	3H	-	1.12	-
	3I	-	0.70	0.26
	3J	-	-	0.30
	3K	-	-	0.70
Organic Nitrogen mg/l				
	3	-	3.10	1.0
	3A	-	0.03	0.4
	3B	-	0.14	0.1
	3C	-	0.13	0.4
	3D	-	0.57	0.1
	3E	-	0.87	0.2
	3F	-	0.50	0.2
	3G	-	1.46	0.3
	3H	-	0.47	-
	3I	-	0.08	0.2
	3J	-	-	0.2
	3K	-	-	0.6

APPENDIX A-4 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
Total Phosphorus mg/l		May 9	May 21	June 4
	3	0.114	1.130	0.733
	3A	0.211	0.035	0.200
	3B	-	0.001	0.200
	3C	-	0.195	0.267
	3D	-	0.023	0.200
	3E	-	0.028	0.300
	3F	-	0.069	0.233
	3G	-	0.005	0.100
	3H	-	0.277	-
	3I	-	0.027	0.333
	3J	-	-	0.100
	3K	-	-	0.200
Total Dissolved Phosphorus mg/l	3	0.008	0.744	0.333
	3A	0.013	0.006	0.200
	3B	-	0.006	0.200
	3C	-	0.126	0.200
	3D	-	0.013	0.200
	3E	-	0.028	0.200
	3F	-	0.055	0.200
	3G	-	0.006	<0.200
	3H	-	0.118	-
	3I	-	0.030	<0.200
	3J	-	-	<0.200
	3K	-	-	<0.200
Dissolved Orthophosphate mg/l	3	0.008	0.616	0.8
	3A	0.014	0.008	0.4
	3B	-	0.003	0.6
	3C	-	0.070	0.4
	3D	-	0.010	0.4
	3E	-	0.002	0.4
	3F	-	0.022	0.4
	3G	-	0.002	<0.1
	3H	-	0.060	-
	3I	-	0.022	<0.1
	3J	-	-	<0.1
	3K	-	-	<0.1
Alkalinity mg/l				
	3	63	134	-
	3A	81	116	-
	3B	-	142	140
	3C	-	97	-
	3D	-	87	90
	3E	-	105	116
	3F	-	86	96
	3G	-	336	308
	3H	-	114	-
	3I	-	177	192
	3J	-	-	120
	3K	-	-	312

APPENDIX A-4 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
		May 9	May 21	June 4
Biochemical Oxygen				
	3	9	59	-
	3A	31	12	-
	3B	-	2	-
	3C	-	2	-
	3D	-	8	-
	3E	-	57	-
	3F	-	10	-
	3G	-	6	-
	3H	-	116	-
	3I	-	5	-
	3J	-	-	-
	3K	-	-	-
pH				
	3	7.1	6.9	-
	3A	7.7	7.0	-
	3B	-	7.1	7.6
	3C	-	7.1	-
	3D	-	6.9	7.7
	3E	-	6.8	7.3
	3F	-	6.9	7.6
	3G	-	7.8	8.0
	3H	-	6.8	-
	3I	-	7.7	7.9
	3J	-	-	7.4
	3K	-	-	7.7
Specific Conductance mohm/cm	3	301	574	945
	3A	361	530	590
	3B	-	735	710
	3C	-	450	440
	3D	-	375	440
	3E	-	484	530
	3F	-	718	885
	3G	-	1430	1300
	3H	-	618	-
	3I	-	802	415
	3J	-	-	530
	3K	-	-	825
Color Units				
	3	20	7	35
	3A	40	5	10
	3B	-	2	10
	3C	-	1	100
	3D	-	< 1	10
	3E	-	3	15
	3F	-	25	8
	3G	-	5	20
	3H	-	100	-
	3I	-	< 1	20
	3J	-	-	30
	3K	-	-	150

CONSTITUENT	STATION	SAMPLING DATE May 9	May 21	June 4
Iron µg/l				
	3	4340	832	8400
	3A	14,110	620	500
	3B	-	426	6000
	3C	-	260	6600
	3D	-	1040	300
	3E	-	1308	1300
	3F	-	400	1100
	3G	-	2054	400
	3H	-	620	-
	3I	-	710	800
	3J	-	-	3300
	3K	-	-	87,100
Copper µg/l	3	22	58	10
	3A	42	14	20
	3B	-	6	10
	3C	-	8	100
	3D	-	40	<10
	3E	-	16	<10
	3F	-	22	<10
	3G	-	20	<10
	3H	-	28	-
	3I	-	8	20
	3J	-	-	160
	3K	-	-	520
Lead µg/l	3	82	31	17
	3A	334	15	<10
	3B	-	27	<10
	3C	-	23	<10
	3D	-	53	<10
	3E	-	18	<10
	3F	-	45	20
	3G	-	65	<10
	3H	-	88	-
	3I	-	33	10
	3J	-	-	10
	3K	-	-	1500
Zinc µg/l				
	3	82	146	100
	3A	252	37	100
	3B	-	77	100
	3C	-	35	100
	3D	-	177	< 5
	3E	-	90	200
	3F	-	62	100
	3G	-	52	< 5
	3H	-	100	-
	3I	-	35	< 5
	3J	-	-	< 5

APPENDIX A-4 (cont.)

CONSTITUENT	STATION	SAMPLING DATE		
		May 9	May 21	June 4
Cadmium µg/l				
	3	2.4	0.123	<10
	3A	2.8	0.021	<10
	3B	-	0.021	<10
	3C	-	0.031	<10
	3D	-	0.011	<10
	3E	-	0.013	<10
	3F	-	0.020	<10
	3G	-	0.033	<10
	3H	-	0.019	-
	3I	-	0.021	<10
	3J	-	-	<10
	3K	-	-	<10
Chromium µg/l				
	3	6	31	<10
	3A	10	4	<10
	3B	-	4	<10
	3C	-	4	<10
	3D	-	6	<10
	3E	-	6	<10
	3F	-	5	<10
	3G	-	12	<10
	3H	-	5	-
	3I	-	24	<10
	3J	--	-	<10
	3K	-	-	<10
Aluminum µg/l				
	3	1800	300	180
	3A	7040	150	170
	3B	-	120	600
	3C	-	100	3500
	3D	-	300	300
	3E	-	180	400
	3F	-	180	400
	3G	-	420	260
	3H	-	180	-
	3I	-	270	300
	3J	-	-	220
	3K	-	-	1180
Mercury µg/l				
	3	4.1	-	<0.2
	3A	5.2	0.7	<0.2
	3B	-	0.7	7.4
	3C	-	0.2	1.0
	3D	-	0.3	6.1
	3E	-	0.3	<0.2
	3F	-	0.2	<0.2
	3G	-	0.1	2.4
	3H	-	2.1	1.6
	3I	-	0.2	2.2
	3J	-	-	8.0
	3K	-	-	-

APPENDIX A-5

DEPTH COMPARISON OF PHYSICAL AND CHEMICAL PARAMETERS FOR LAKE STATIONS - June 4, 1974

Constituent	Depth	Station 2	4	5	6	7	8	9	10
Total Solids mg/l	Surface	172	198	196	266	210	192	202	214
	Middle	186	180	180	216	178	-	200	198
	Bottom	204	184	216	238	180	188	214	166
Suspended Solids mg/l	Surface	8	8	8	6	6	4	6	12
	Middle	8	6	10	6	6	-	6	10
	Bottom	8	8	10	8	4	6	10	10
Nitrate as N mg/l	Surface	0.9	1.6	0.9	1.6	1.3	1.3	1.1	1.3
	Middle	1.3	1.1	0.9	1.6	1.3	-	1.3	1.1
	Bottom	1.1	1.1	1.3	1.6	1.3	1.3	1.3	1.6
Ammonia as N mg/l	Surface	0.06	0.06	0.10	0.10	0.06	0.06	0.06	0.06
	Middle	0.06	0.06	0.06	0.10	0.06	-	0.06	0.06
	Bottom	0.06	0.06	0.06	0.10	0.10	0.06	0.10	0.06
Total Kjeldahl Nitrogen mg/l	Surface	0.26	0.26	0.36	0.30	0.46	0.46	0.26	0.66
	Middle	0.66	0.46	0.46	0.50	0.36	-	0.46	0.26
	Bottom	0.46	0.26	0.46	0.50	0.40	0.46	0.50	0.66

APPENDIX A-5 (cont.)

DEPTH COMPARISON OF PHYSICAL AND CHEMICAL PARAMETERS FOR LAKE STATIONS - June 4, 1974

Constituent	Depth	Station 2	4	5	6	7	8	9	10
Organic Nitrogen mg/l	Surface	0.20	0.20	0.30	0.20	0.40	0.40	0.20	0.60
	Middle	0.66	0.46	0.46	0.50	0.36	-	0.46	0.26
	Bottom	0.46	0.26	0.46	0.50	0.40	0.46	0.50	0.66
Organic Nitrogen mg/l	Surface	0.20	0.20	0.30	0.20	0.40	0.40	0.20	0.60
	Middle	0.60	0.40	0.40	0.40	0.30	-	0.40	0.20
	Bottom	0.40	0.20	0.40	0.40	0.30	0.40	0.40	0.60
Total Phosphorus mg/l	Surface	0.167	0.133	0.067	0.167	0.233	0.167	0.200	0.200
	Middle	0.133	0.500	0.167	0.167	0.267	-	0.200	0.400
	Bottom	0.200	0.133	0.167	0.200	0.267	0.233	0.133	0.467
Total Dissolved Phosphorus mg/l	Surface	<0.03	0.067	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
	Middle	<0.03	<0.03	0.067	<0.03	<0.03	-	<0.03	<0.03
	Bottom	<0.03	<0.03	0.033	<0.03	<0.03	<0.03	<0.03	<0.03
Alkalinity mg/l	Surface	108	104	106	222	188	182	188	186
	Middle	110	106	262	194	182	-	196	210
	Bottom	102	106	182	212	190	190	168	174

APPENDIX A-5 (cont.)

DEPTH COMPARISON OF PHYSICAL AND CHEMICAL PARAMETERS FOR LAKE STATIONS - June 4, 1974

Constituent	Depth	Station							
		2	4	5	6	7	8	9	10
Biochemical Oxygen Demand mg/l	Surface	-	-	-	2	0	5	2	5
	Middle	-	-	-	0	0	-	1	4
	Bottom	-	-	-	1	0	0	1	4
Dissolved Orthophosphate mg/l	Surface	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	Middle	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1
	Bottom	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
pH	Surface	8.0	7.4	8.0	7.3	7.5	7.6	7.6	7.6
	Middle	7.5	7.6	7.3	7.3	7.5	-	7.5	7.5
	Bottom	7.8	7.8	7.2	2.3	7.5	7.7	7.5	7.5
Specific Conductance mohm/cm	Surface	385	385	415	355	355	330	340	415
	Middle	385	385	385	355	355	-	355	385
	Bottom	415	385	355	355	330	330	354	385
Color Units	Surface	10	15	15	15	15	10	10	40
	Middle	10	15	15	15	15	-	15	30
	Bottom	10	15	15	15	15	15	15	25

APPENDIX A-5 (cont.)

DEPTH COMPARISON OF PHYSICAL AND CHEMICAL PARAMETERS
FOR LAKE STATIONS - June 4, 1974

Constituent	Depth	Station							
Iron µg/l		2	4	5	6	7	8	9	10
	Surface	100	100	200	200	100	50	100	300
	Middle	300	200	200	100	100	-	200	100
	Bottom	200	200	600	200	200	100	700	100
Copper µg/l									
	Surface	<10	<10	<10	<10	<10	<10	<10	<10
	Middle	<10	<10	<10	<10	<10	-	<10	<10
	Bottom	<10	<10	<10	<10	<10	<10	<10	180
Lead µg/l									
	Surface	<10	10	10	10	10	10	10	10
	Middle	10	10	10	10	10	-	10	10
	Bottom	10	10	10	10	10	10	10	10
Zinc µg/l									
	Surface	<5	<5	<5	<5	<5	<5	<5	<5
	Middle	<5	<5	<5	<5	<5	-	<5	<5
	Bottom	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium µg/l									
	Surface	<10	10	10	10	10	10	10	10
	Middle	10	10	10	10	10	-	10	10
	Bottom	10	10	10	10	10	10	10	10

APPENDIX A-5 (cont.)

DEPTH COMPARISON OF PHYSICAL AND CHEMICAL PARAMETERS
FOR LAKE STATIONS - June 4, 1974

Constituent	Depth	Station 2	4	5	6	7	8	9	10
Chromium µg/l	Surface	<10	<10	<10	<10	<10	<10	<10	<10
	Middle	<10	<10	<10	<10	<10	<10	<10	<10
	Bottom	<10	<10	<10	<10	<10	<10	<10	<10
Aluminum µg/l	Surface	300	300	200	240	150	170	50	160
	Middle	500	400	300	120	340	-	150	120
	Bottom	120	140	400	300	120	100	300	300
Mercury µg/l	Surface	4.0	4.7	6.7	5.4	1.5	1.3	1.2	3.3
	Middle	3.5	4.3	5.8	1.3	1.2	-	1.6	3.3
	Bottom	2.9	4.0	4.3	2.0	0.9	1.3	2.0	2.4

APPENDIX A-6

TEMPERATURE AND DISSOLVED OXYGEN

9/27/73

Station	Time	Depth ft.	Temp. ^{o}C	D.O. ppm
2	0700	Surface	18.5	8.0
4	0654	Surface	19.0	8.5
5	0708	Surface	18.5	8.3
6	0729	Surface	19.0	8.1
7	0726	Surface	19.0	8.0
8	0720	Surface	19.0	8.1
9	0735	Surface	19.0	7.9
10	0745	Surface	19.0	7.8

APPENDIX A-6 (cont.)

TEMPERATURE AND DISSOLVED OXYGEN

10/25/73

Station	Time	Depth ft.	Temp. °C	D.O. ppm	Secchi (m)
2	1230	Surface	13.5	11.2	1.0
4	1245	Surface	13.5	10.0	1.4
4A	1250	Surface	17.0	2.2	0.3
4B	1255	Surface	18.0	2.7	0.2
5	1300	Surface	14.0	10.4	1.2
6	1330	Surface	15.0	6.8	0.7
6A	1332	Surface	15.0	6.5	0.6
6B	1335	Surface	15.5	5.9	0.4
6C	1337	Surface	18.0	4.8	0.1
7	1320	Surface	15.0	9.4	1.3
8	1315	Surface	15.0	9.6	1.2
9	1345	Surface	15.0	8.8	1.2
10	1350	Surface	15.0	7.5	1.1
Pennelec	1520	Surface	19.0	8.3	0.8

Note:

4A - located 200 ft. out from Mill Creek confluence
4B - located 100 ft. out from Mill Creek confluence
6A - located 100 ft. off shore from Hammermill Paper Company's stacks
6B - located 50 ft. from Hammermill's wastewater boom
6C - located 500 ft.east of Hammermill's wastewater boom, about 100 ft. off shore

APPENDIX A-6 (cont.)

TEMPERATURE AND DISSOLVED OXYGEN

10/25/73 - 10/26/73

Station	Time	Depth ft.	Temp. °C	DO ppm	Secchi (m)
2	1545	Surface	14.5	10.8	1.1
2	1910	Surface	13.0	10.6	--
2	0735	Surface	13.0	9.7	--
2	1100	Surface	13.0	9.6	--
4	1620	Surface	14.0	9.6	1.3
4	1851	Surface	13.5	9.2	--
4	0744	Surface	14.0	8.7	--
4	1150	Surface	15.5	4.8	--
4A	1855	Surface	17.0	0.9	0.3
4A	0750	Surface	14.5	0.7	--
4D	1850	Surface	13.5	6.7	--
5	1700	Surface	15.0	10.5	1.2
5	1845	Surface	14.0	10.6	--
5	0755	Surface	14.0	9.6	--
6	1800	Surface	15.0	6.8	0.8
6	0825	Surface	14.5	5.7	--
7	1750	Surface	15.0	8.6	1.3
7	0812	Surface	14.0	7.6	--
8	1720	Surface	15.0	8.7	1.2
8	0808	Surface	14.0	8.3	--
9	1806	Surface	14.5	9.4	1.2
9	0830	Surface	14.0	8.3	--
10	1815	Surface	15.0	7.2	1.0
10	0835	Surface	14.0	5.7	--

APPENDIX A-6 (cont.)

TEMPERATURE AND DISSOLVED OXYGEN

12/4/73

Station	Time	Depth ft.	Temp.°C	D.O. ppm	Secchi (m)
1	1310	Surface	14.5	--	--
2	1015	Surface	7.0	9.3	1.3
3	1340	Surface	15.0	D.O. Meter Out-of-Order	--
4	1225	Surface	7.0		1.5
4A	1230	Surface	11.5		0.5
5	1030	Surface	7.5		1.6
6	1130	Surface	7.8		0.9
6A	1140	Surface	9.0		0.5
7	1120	Surface	7.6		1.0
8	1110	Surface	7.8		0.8
8	1112	10	7.5		--
9	1150	Surface	7.8		0.9
10	1200	Surface	8.1		0.6

Notes:

1 - Cascade Creek south of confluence with bay
3 - Mill Creek below Erie sewage treatment plant
4A- located 200 ft. out from Mill Creek confluence
6A- located 100 ft. off shore from Hammermill Paper Company's stacks

APPENDIX A-6 (cont.)

TEMPERATURE AND DISSOLVED OXYGEN

5/22/74

Station	Time	Depth ft.	Temp.°C	D.O. ppm	Secchi (m)
2	0925	Surface	15.5	9.4	-
2	0925	3	15.5	10.4	-
2	0925	6	15.5	10.4	-
2	0930	9	15.5	10.9	-
2	0930	12	15.5	10.9	-
2	1140	Surface	17.0	-	1.4
2	1555	Surface	16.5	10.6	1.4
4	1147	Surface	16.5	-	1.3
4	1610	Surface	16.5	10.0	1.4
4A	0935	Surface	17.0	8.1	-
5	1152	Surface	16.9	-	1.2
5	1630	Surface	17.4	10.1	1.4
6	1212	Surface	14.0	-	0.8
6A	1215	Surface	15.5	9.6	0.2
6B	1745	Surface	14.5	-	0.4

Note:

4A - located 200 ft. out from Mill Creek confluence.

APPENDIX A-6 (cont.)

TEMPERATURE AND DISSOLVED OXYGEN

6/4/74 - 6/5/74

Station	Time	Depth ft.	Temp. °C	D.O. ppm
2	1615	1	21.4	10.2
2	-	3	21.0	10.3
2	-	6	20.8	10.3
2	-	9	20.0	10.7
2	-	12	18.6	9.9
2	-	15	17.5	7.5
2	-	18	17.0	7.0
2	-	21	16.5	6.2
4	1840	1	22.0	9.9
4	-	3	21.0	10.8
4	-	6	20.8	11.2
4	-	9	20.5	11.2
4	-	12	20.0	10.1
5	1820	1	22.0	10.0
5	-	3	21.8	10.2
5	-	6	19.5	10.7
5	-	9	19.2	10.2
5	-	12	19.0	9.4
6	1205	1	18.5	7.4
6	-	3	18.2	7.6
6	-	6	18.0	7.9
6	-	9	17.5	7.7
6	-	12	16.5	5.8
6A	2000	3	18.5	5.7
7	1055	1	18.6	8.7
7	-	3	18.5	9.0
7	-	6	18.2	9.5
7	-	9	17.5	9.5
7	-	12	17.0	9.8
7	-	15	15.8	9.5
7	-	18	15.6	9.6
8	1030	1	18.0	11.6
8	-	3	17.8	11.1
8	-	6	17.6	10.9
9	1445	1	19.2	9.0
9	-	3	19.0	9.2
9	-	6	18.5	9.4
9	-	9	18.1	9.4
9	-	12	17.5	9.0
9	-	15	17.0	8.8
9	-	18	16.0	7.6
9	-	21	15.3	7.6
9	-	24	15.0	7.8
10	1900	1	20.0	5.8
10	-	3	19.0	6.8
10	-	6	18.5	6.5
10	-	9	18.0	4,5
12	2010	4	20.0	7.3
12A	2030	-	35.0	-
GE	1950	-	22.5	-

APPENDIX A-7

SEDIMENT ANALYSIS

June 4-5, 1974

CONSTITUENT mg/l	STATION 2	4	5	7	8	9
Ammonia as N						
Free	500	10	2000	50	<6	40
Fixed	400	50	1000	120	10	10
Nitrate as NO_3	<50	100	< 50	50	50	250
Total Phosphate as PO_4	4200	1440	5600	2120	2000	720
Ortho Phosphate as PO_4	3760	1120	4680	2040	1760	720
Iron as Fe	31,600	10,480	42,280	29,800	6,320	24,840
Copper as Cu	104	22.4	108	37.6	3.2	32
Zinc as Zn	400	84	450	132	32	140
Chromate as CrO_4	120	36	180	60	16	56
Aluminum as Al	14,720	3440	17.920	11,200	2000	9120
Lead as Pb µg/l	200	64	164	32	< 10	28
Cadmium as Cd µg/l	<10	< 10	<10	<10	<10	<10
Mercury as Hg µg/l	496	416	736	192	28	200

APPENDIX B

BACTERIOLOGICAL DATA

APPENDIX B-1

TOTAL COLIFORM BACTERIA FOR LAKE STATIONS
colonies 100/ml

STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
2	13,000	18,500	19,000	2600	500	-
4	2900	17,300	38,000	-	1150	-
4A	-	-	1,000,000	-	-	-
5	3400	14,200	3600	1700	-	-
6	100	1500	4000	5000	3700	1100
6A	-	-	-	-	-	400
7	170	2500	9500	1600	5600	8100
8	240	8800	5700	1700	200	200
9	20	4900	6600	-	1100	1800
10	120	2700	2850	-	100	207,000
11	-	-	-	4900	-	
12	-	-	-	-	-	5200

TABLE FECAL COLIFORM BACTERIA FOR LAKE STATIONS
colonies 100/ml

STATION	SAMPLING DATE 9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
2	1800	880	200	36	340	-
4	3800	3240	3100	-	800	-
4A	-	-	290,000	-	-	-
5	208	560	100	44	50	-
6	< 10	30	600	28	40	30
6A	-	-		-	-	270
7	< 10	30	100	<10	70	210
8	16	50	400	<10	10	10
9	<10	10	400	-	95	10
10	<10	10	100	-	60	1990
11	-	-	-	32	-	-
12	-	-	-	-	-	170

APPENDIX B-1 (cont.)

TOTAL BACTERIA PLATE COUNTS FOR LAKE STATIONS
colonies/ml

STATION	SAMPLING DATE					
	9-27-73	10-26-73	12-4-73	12-27-73	5-21-74	6-4-74
2	75,000	18,000	11,000	320	100	-
4	49,000	270	2000		25,000	-
4A	-	-	250,000	-	-	-
5	4,000	500	10	800	30,000	-
6	5,000	12,000	9000	3000	15,000	1,200,000
6A	-	-	-	-	-	9,400,000
7	7,500	11,000	13,000	275	30,000	150,000
8	18,000	6,000	525	385	-	20,000
9	11,500	16,000	1400	-	4200	306,000
10	14,000	8200	350	-	6200	900,000
11	-	-	-	575	-	-
12	-	-	-	-	-	920,000

APPENDIX B-2

BACTERIA CONCENTRATIONS IN CASCADE CREEK

SAMPLING DATE

STATION	12-28-73			5-8/9-74			6-4-74		
	TOTAL BACTERIA col/ml	TOTAL COLIFORM BACTERIA col/100ml	FECAL COLIFORM BACTERIA col/100ml	TOTAL BACTERIA col/ml	TOTAL COLIFORM BACTERIA col/100ml	FECAL COLIFORM BACTERIA col/100ml	TOTAL BACTERIA col/ml	TOTAL COLIFORM BACTERIA col/100ml	FECAL COLIFORM BACTERIA col/100ml
1	4100	12,000	1200	2300	16,200	230	370,000	120,000	140
1A	900	800	< 10	1400	17,100	310	15,000	1500	130
1B	2000	3300	24	10,000	4300	20	45,000	540	260
1C	1000	3500	368	6000	15,500	690	170,000	4900	40
1D	-	-	-	160,000	9400	20	83,000	64,000	170
1E	-	-	-	100,000	14,800	850	1,800,000	7800	1170
1F	-	-	-	5000	1000	< 10	34,000	2800	660
2	-	-	-	80,000	45,000	-	-	-	-
2A	-	-	-	14,000	4,000	-	-	-	-

APPENDIX B-3

COMPARISON OF BACTERIA CONCENTRATIONS

FOR STATIONS 1 AND 3

CONSTITUENT	STATION	9-27-73	10-26-73	12-4-73	12-28-73	5-8/9-74	5-21-74	6-4-74
TOTAL BACTERIA colonies/ml	1	39,000	8600	20,000	4100	2300	900,000	370,000
	3	40,000	40,000	150,000	130,000	7700	300,000	-
TOTAL COLIFORM BACTERIA colonies/100 ml	1	37,000	12,300	99,500	12,000	16,200	6400	120,000
	3	20,000	>1,000,000	-	72,000	19,000	136,000	-
FECAL COLIFORM BACTERIA colonies/100 ml	1	4600	11,200	1100	1200	230	20	140
	3	12,000	>1,000,000	300,000	32,400	370	200,000	-

APPENDIX B-4

DEPTH COMPARISON OF BACTERIA

June 4, 1974

	Depth	Station 6	7	8	9	10
Total Bacteria colonies/ml	Surface	1,200,000	150,000	20,000	306,000	900,000
	Middle	1,150,000	300,000	-	24,000	90,000
	Bottom	20,000,000	1,500,000	450,000	9,000	128,000
Total Coliform Bacteria colonies/100 ml	Surface	1100	8100	200	1800	207,000
	Middle	1600	800	-	1200	100
	Bottom	180,000	400	900	500	570
Fecal Coliform Bacteria colonies/100ml	Surface	30	210	10	10	1990
	Middle	20	20	-	20	20
	Bottom	50	10	10	10	30

APPENDIX C

PLANKTON DATA

APPENDIX C-1

DISTRIBUTION OF LAKE ERIE PLANKTON

Organisms/Liter September 27, 1973

	STATION									
	1	2	3	4	5	6	7	8	9	10
ALGAE										
Chlorophyta										
Chlorella	-	1500	-	1600	-	-	-	2000	-	-
Coelastrum	-	-	-	-	2000	-	-		400	400
Micractinium	-	-	-	-	4000	-	-	-	-	-
Oocystis	-	-	-	800	-	-	-	-	-	800
Palmella	-	-	-	-	-	-	-	-	1600	-
Pediastrum	-	1800	-	-	6000	280	1200	6000	1200	400
Protococcus	-	-	-	-	-	-	-	2000	-	-
Sphaerocystis	-	-	-	-	2000	-	-	-	-	-
Staurastrum	-	-	-	800	-	-	-	-	-	-
Spirogyra	-	-	-	-	-	-	1200	-	-	-
Ulothrix	-	600	-	-	-	-	-	-	400	-
Hyalotheca	-	-	-	-	-	-	-	16000	400	-
Chrysophyta										
Fragillaria	-	1800	5500	1600	2000	1440	2400	-	3600	2000
Navicula	-	-	-	-	-	-	1200	2000	-	-
Tabellaria	-	600	-	-	2000	7800	21600	-	12400	-
Cyanophyta										
Anabaena	-	300	-	-	6000	-	-	-	400	-
Aphanazomena	-	900	-	1600	-	-	2400	-	-	-
Gomphospheria	-	-	-	800	-	-	-	-	-	-
Oscillatoria	-	5400	-	-	14000	580	1200	2000	1600	-
Zooplankton										
Calanoida	-	-	-	-	2000	-	-	-	-	-
Vorticella	-	-	-	800	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON

Organisms/Liter

October 25, 1973

	STATION									
	1	2	3	4	5	6	7	8	9	10
ALGAE										
Chlorophyta										
Ankistrodesmus	-	-	-	-	840	-	100	-	80	230
Chlorella	-	360	2100	270						110
Coelastrum	-	-	-	-	-	200	100	-	240	-
Palmella	-	120	-	-	-	-	200	-	-	-
Pediastrum	-	3120	1480	2580	1680	500	800	1140	800	-
Selenastrum	-	-	-	-	-	100	-	-	-	-
Staurastrum	-	-	-	410	-	100	-	170	-	-
Ulothrix	-	-	-	-	-	-	-	-	320	-
Chrysophyta										
Dinobryon	-	-	-	-	140	-	-	-	80	-
Diatoms	-	-	-	-	-	-	-	-	-	-
(individual)	180000	840	2540	270	140	-	400	-	-	-
Diatoms (colonies)	-	-	-	410	420	300	100	350	400	110
Cyanophyta										
Aphanazomenon	-	4200	420	950	3920	600	800	530	560	1790
Nodularia	-	-	-	-	140	-	200	350	-	-
Oscillatoria	-	-	-	140	-	100	-	-	-	-
Zooplankton										
Protozoans	140000	-	-	-	-	-	-	-	-	-
Euglenaceae	-	-	-	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON

Organisms/Liter

December 4, 1973

	STATION									
	1	2	3	4	5	6	7	8	9	10
ALGAE										
Chlorophyta										
Ankistrodesmus	-	-	-	620	-	190	-	1500	-	-
Chlorella	-	610	-	-	1150	190	-	300	-	-
Golenkinia	-	-	-	310	-	-	300	-	-	-
Palmella	-	-	-	160	-	-	-	-	-	-
Pediastrum	-	-	-	310	290	-	300	-	150	-
Rhizoclonium	160	450	-	310	1250	-	-	-	-	150
Staurastrum	-	-	-	-	-	-	-	-	-	150
Scenedesmus	-	150	-	-	-	-	300	-	-	-
Ulothrix	-	450	-	1560	110	-	300	-	150	-
Chrysophyta										
Mallomenas	-	-	-	-	-	-	-	-	150	-
Diatoms	640	2890	2600	1400	1340	3070	3300	2100	1060	1060
Cyanophyta										
Chroococcus	-	-	-	160	-	190	-	-	-	-
Oscillatoria	-	-	-	-	190	-	-	-	-	-
Zooplankton										
Water mites	-	150	-	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON

Organisms/Liter

December 27, 1973

	STATION											
	1	2	3	5	6	7	8	11	1A	1B	1C	1D
ALGAE												
Chlorophyta									0			0
Ankistrodesmus	-	-	-	300	670	180	360	350	-	-	-	-
Chlorella	-	80	-	150	-	90	-	70	-	-	-	-
Coelastrum	-	-	-	150	-	90	-	-	-	-	-	-
Eudorina	-	40	-	-	-	-	-	-	-	-	-	-
Palmella	-	-	-	-	-	-	-	-	-	-	-	-
Pediastrum	-	240	-	300	340	180	180	-	-	-	-	-
Rhizoclonium	-	280	-	300	250	-	-	210	-	-	-	-
Selenastrum	-	-	-	150	-	-	-	-	-	-	-	-
Scenedsmus	-	-	-	150	-	90	-	-	-	-	-	-
Staurastrum	-	40	-	150	80	360	-	-	-	-	-	-
Tetastrum	-	-	-	-	-	-	-	70	-	-	-	-
Chrysophyta									0			0
Diatoma	40	1280	660	1200	2440	1800	2000	1120	-	120	140	-
Cyanophyta									0			
Oscillatoria	-	80	-	300	-	-	270	70	-	-	-	-
Euglenophyta									0			
Phacus	-	-	-	150	-	-	-	-	-	-	-	-
Zooplankton												
Water Mites	-	-	-	150	80	-	-	210	0	-	-	-
Rotifera	-	-	-	-	80	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

Organisms/Liter

DISTRIBUTION OF LAKE ERIE PLANKTON

May 29, 1974

	STATION									
	1	2	3	4	5	6	7	8	9	10
ALGAE										
Chlorophyta										
Ankistrodesmus	-	-	-	-	-	158	360	158	-	-
Microspora	-	-	-	-	-		-	-	122	-
Mougeotia	-	66	-	-	116	-	-	-	-	-
Pediastrum	-	66	-	-	232	-	-	-	-	-
Scenedesmus	-	-	-	158	232	-	-	-	-	-
Ulothrix	-	264	-	79	116	2213	3067	6006	1825	5559
Micractiuium	-	-	582	-	232	-	-	-	-	222
Stigeoclonium	-	-	-	-	-	-	-	-	-	-
Staurastrum	-	-	-	-	116	-	-	-	-	-
Chrysophyta										
Asterionella	-	925	-	1106	3715	948	1804	1738	608	890
Fragillario	11430	1983	1164	790	1393	158	541	316	608	-
Naricula	1905	-	1745	-		-	-	-	-	222
Nitzschva	1270	-	-	-		-	-	-	122	-
Tabellaria	8255	66	-	-	116	316	1083	1580	487	667
Gynedra	4445	132	-	-		-	-	-	-	-
Dinobryon	-	-	-	-	116	-	-	158	-	-
Zooplankton										
Water Mites	-	-	-	316	580	316	180	-	-	222
Rotifers	-	-	-	158	-	-	-	-	-	-
Flagellated	-	-	-	-	-	-	-	-	-	-
Protozoans	3810	-	116363	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON

Organisms/Liter

June 18, 1974

	STATION						
	1	1A	1B	1C	10	1E	1F
ALGAE							
Chlorophyta							
Ankistrodesmus	-	-	-	-	-	-	-
Coelastrum	-	-	-	-	-	-	-
Mougeotia	-	-	-	-	-	-	-
Oedogonium	-	-	-	-	-	-	-
Pediastrum	-	-	-	-	-	-	-
Protococcus	-	-	-	-	-	-	-
Ulothrix	-	-	-	-	-	-	-
Chrysophyta							
Asterionella	-	-	-	-	-	-	-
Cyclotella	-	-	-	-	-	-	-
Diatoms	120	-	-	4746	-	-	-
Fragillaria	2520	-	22,360	18,983	-	-	-
Naricula	120	-	-	-	-	-	1782
Nitzschia	3780	-	-	-	-	-	-
Tabellaria	4536	-	-	-	-	-	-
Synedia	8820	-	-	-	-	-	-
Euglenophyta							
Zooplankton	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON (cont.)

Organisms/Liter

June 18, 1974

	STATION									
	6	6M	6B	7	8	8B	9	9M	9B	10S
ALGAE										
Chlorophyta	-	-	-	-	-	-	-	-	-	-
Ankistrodesmus	-	-	-	-	-	-	1271	-	-	-
Closteridium	-	2020	-	-	-	-		-	-	-
Coelastrum	-	-	-	-	-	-	-	-	-	1414
Mougeotia	-	-	-	-	-	-	1271	-	-	2828
Oedogonium	-	-	-	-	-	-	-	1994	1784	-
Pediastrum	2023	-	-	2864	-	-	-	-	-	-
Protococcus				2864						
Ulothrix	-	-	2376	-	3111	1720	-	-	1784	-
Chrysophyta										
Asterionella	-	-	4752	-	-	1720	-	-	1784	-
Cyclotella	-	-	-	-	-	-	-	-	1784	-
Fragillaria	-	-	-	-	-	-	-	-	-	2828
Navicula	-	-	2376	-	-	-	-	-	-	-
Nitzschia	-	-	-	-	-	-	-	-	-	-
Tabellaria	2023	4040	-	2864	-	-	-	-	-	-
Synedra	-	-	-	-	-	-	-	-	-	-
Diatoms	-	-	-	-	-	-	-	-	-	-
Euglenophyta										
Euglena	-	-	-	-	-	-	-	-	-	-
Zooplankton										
Rotifers	-	-	2376	-	-	-	-	-	-	-

APPENDIX C-1 (cont.)

DISTRIBUTION OF LAKE ERIE PLANKTON (cont.)

Organisms/Liter

June 18, 1974

	STATION			
	10M	10B	12	12A
ALGAE				
Chlorophyta				
Coelastrum	-	-	-	-
Mougeotia	-	1595	3256	-
Protococcus	-	1595	-	-
Chrysophyta				
Asterionella	-	-	1085	-
Fragillaria	-	-	1085	-
Tabellaria	-	-	1085	1388
Euglenophyta				
Euglena	-	-	-	1388
Zooplankton				
Water Mites	-	1595	-	-

APPENDIX C-2

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

September 27, 1973

DIVISION	STATION 1	2	3	4	5	6	7	8	9	10
Chlorophyta	-	3900	-	3200	14000	280	2400	10000	3600	1600
Chrysophyta	-	2400	-	1600	4000	9240	25200	18000	16400	2000
Cyanophyta	-	6600	5500	2400	20000	580	3600	2000	2000	-
Euglenophyta	-	-	-	-	-	-	-	-	-	-
Zooplankton	-	-	-	800	2000	-	-	-	-	-
Total	0	12900	5500	8000	40000	10100	31200	30000	22000	3600

APPENDIX C-2 (cont.)

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

October 25, 1973

DIVISION	STATION 1	2	3	4	5	6	7	8	9	10
Chlorophyta	-	3600	3580	3260	2520	900	1200	1310	1440	340
Chrysophyta	180,000	840	2540	680	700	300	500	350	480	110
Cyanophyta	-	4200	420	1090	4060	700	1000	880	560	1790
Euglenophyta	-	-	-	-	-	-	-	90	-	-
Zooplankton	140,000	-	-	-	-	-	-	-	-	-
Total	320,000	8640	6540	5030	7280	1900	2700	2630	2480	2240

APPENDIX C-2 (cont.)

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

December 4, 1973

DIVISION	STATION									
	1	2	3	4	5	6	7	9	9	10
Chlorophyta	160	1660	-	3270	2800	380	1200	1800	300	300
Chrysophyta	640	2890	2600	1400	1340	3070	3300	2100	1210	1060
Cyanophyta	-	-	-	160	190	190	-	-	-	-
Euglenophyta	-	-	-	-	-	-	-	-	-	-
Zooplankton	-	150	-	-	-	-	-	-	-	-
Total	800	4700	2600	4830	4330	3640	4500	3900	1510	1360

APPENDIX C-2 (cont.)

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

December 27, 1973

DIVISION	STATION 1	2	3	5	6	7	8	11
Chlorphyta	-	680	-	1650	1340	990	540	700
Chrysophyta	40	1280	660	1200	2440	1800	2000	1120
Cyanophyta	-	80	-	300	-	-	270	70
Euglenophyta	-	-	-	150	-	-	-	-
Zooplankton	-	-	-	150	160	-	-	210
Total	40	2040	660	3450	3940	2790	2810	2100

APPENDIX C-2 (cont.)

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

May 29, 1974

DIVISION	STATION 1	2	3	4	5	6	7	8	9	10
Chlorophyta	-	396	582	237	1044	2371	3427	6164	1947	5781
Chrysophyta	17,305	3106	2909	1896	5340	1422	3428	2792	1825	1779
Cyanophyta	-	-	-	-	-	-	-	-	-	-
Euglenophyta	-	-	-	-	-	-	-	-	-	-
Zooplankton	3810	-	116,363	474	580	316	180	-	-	222
Total	21,115	3502	119,854	2607	6964	4109	7035	8956	3772	7782

APPENDIX C-2 (cont.)

MAJOR DIVISIONS OF LAKE ERIE PLANKTON

Organisms/Liter

June 18, 1974

DIVISION	STATION 1	6	7	8	9	10	12
Chlorophyta	0	2023	5728	3111	2542	4242	3256
Chrysophyta	19,896	2023	2864	-	-	2828	4340
Cyanophyta	-	-	-	-	-	-	-
Euglenophyta	-	-	-	-	-	-	-
Zooplankton	-	-	-	-	-	-	-
Total	19,896	4046	8592	3111	2542	7070	7596

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-905/9-74-015	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Water Pollution Investigation: Erie, Pennsylvania Area		5. REPORT DATE March 1975
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) F. X. Browne, Ph.D., P.E.		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Betz Environmental Engineers, Inc. One Plymouth Meeting Mall Plymouth Meeting, Pennsylvania 19462		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-01-1578
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency - Regions V & III Enforcement Division, 230 S. Dearborn St., Chicago, IL 60604 Enforcement Division, 6th & Walnut St.-Curtis Bldg., Philadelphia, PA 19106		13. TYPE OF REPORT AND PERIOD COVERED Final Report - Water Quality
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Project Officers: Howard Zar and Nick DeBenedictis

16. ABSTRACT

A study of Presque Isle Bay and its tributaries was performed to evaluate present water quality and to determine cause and effect relationships between wastewater discharges and water quality. Field sampling of Presque Isle Bay, its tributaries and Erie Harbor was performed during the fall and winter of 1973 and the spring of 1974. Special wastewater studies were performed for Penn Central and for eight select industries. Garrison Run, a tributary of Presque Isle Bay, was investigated to determine sources of wastewater entering the stream.

In general, water quality in Presque Isle Bay and Erie Harbor was good except for the presence of high levels of total and fecal coliform. Localized areas of degraded water quality were found in a few areas. Poor water quality was observed in the bay area around the confluence of Mill Creek and in the lake area adjacent to Hammermill Paper Company. Water quality in the three tributary streams was degraded and indicated the presence of sanitary and industrial wastewaters. Mill Creek appears to contribute the highest pollutional load to Presque Isle Bay.

(continued on next page)

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Quality, Water Pollution, Aquatic Biology	Presque Isle Bay Lake Erie Great Lakes Garrison Run Penn Central Chemical Parameters Physical Parameters	13B 6F 8H

18. DISTRIBUTION STATEMENT Limited supply without charge from EPA, Regions III & V. At cost of publication from National Technical Information Serv.	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
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EPA Form 2220-1 (9-73)

Various continuous and intermittent wastewater discharges to Garrison Run were identified and characterized. Past operations of the Penn Central yards have produced areas where the ground is impregnated with oil. This oil is apparently discharged to Garrison Run via stormwater drains during periods of rain.